Mining, Ores, Minerals, Geophysics Oceanography

WORKING GROUP 9

सत्यमेव जयते

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CONTENTS

Changeover from Bord and Pillar to Longwall Mining

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In future, mechanization and automation will play a major role in the industrial and economic development of the countries the world over. The modern index to living standards is the amount of power available per head of population. Power is the key to production. The age of nuclear power has already begun and inevitably, as it grows it will ultimately transform life as we know it now. Until then, there will be, however, a transition period with an insatiable demand for more and more power from all possible sources.

Coal will have a big part to play in meeting this demand, provided it is sold at competitive rates with other fuels and forms of energy.

While production costs of coal in other parts of the world have been falling due to mechanization and the use of latest techniques at various phases of the coal industry, it is not so in India. It is expected that this trend will continue in future as well and that the production costs in these countries will go down further by at least 20 per cent during the next decade. It is essential that we in India gear up our production planning in such a manner that productivity increases and there is an ultimate reduction in coal prices.

Presently, we in India face a challenge of rising costs of production of coal and stagnant productivity. In order to meet this challenge a better liaison must exist between the various research institutions concerned with the problems of coal industry, e.g. CMRS, Dhanbad; CFRI, Jealgora; National Coal Development Corporation, Indian Bureau of Mines, and the Industry in the private sector so that re-orientation of applied technology and management techniques is done according to the best interests of the industry.

The problems of the coal industry, which are in the forefront, presently are those of mine-working, mine-ventilation and deep-mining. The problem of recovery of coal is closely linked with the method of extraction. It should be realized that the method of extraction has a great bearing on productivity, economics, transport, and ventilation of the mine. For want of planning ahead, a large amount of coal standing in pillars of thick seams for many many years presents a problem, the solution of which has to be found out, particularly in areas where no stowing material is available.

Generally, the best method is that which will produce largest amount of lump coal. Coal for coking is an exception. Longwall faces produce

the most lumpy coal, so from this point of view and under favourable conditions longwall methods are best. Longwall methods, divided into Advancing and Retreating longwall are used extensively in other countries. Instead of opening rooms with intervening pillars, coal is mined from a continuous face. As work advances or retreats, the roof is allowed to cave, haulage-ways and airways being kept open by packwalls of waste (gob). By this method the recovery is almost cent per cent.

The fundamental principle of longwall method as compared to bord and pillar system is the complete removal of the entire seam in one operation, by carrying a continuous working face, leaving no pillars and allowing the roof to cave behind the face.

In this method of mining, production faces are generally distinguished by their considerable extent. Long continuous faces possess a number of major advantages. First, they yield more coal. Secondly, they allow the maximum use of coal combines, cutting machines and conveyors. When necessary, longwalls can be serviced not by one but two combines or coal cutters. A face extending for 100 metres can be serviced by one conveyor. In walls of greater length two or three conveyors can be put up in tandem. Thirdly, in longwalls, all other conditions being equal, the production programme can be fulfilled with a minimum number of active walls. This reduces the number of development openings and consequently the cost of their maintenance and simplifies the transporation system. Fourthly, supervision of mining operations is much simpler.

In India, working thick seams with complete hydraulic sand stowing has been found to be extremely costly and in some cases difficult for want of stowing material.

In Indian mines, where stowing material is difficult to get, in the case of regular thick seams with a dip less than 50°, if the roof and floor are almost parallel, the extraction should be carried out, whatever the seam thickness, by inclined slices parallel to the roof and floor, the work carried out to the dip with caving or stowing or to the rise with stowing. These methods are being applied successfully at Blanzy Coal Mines in France.

Presently, in India, the depillaring of thick seams is a problem. The recovery of almost all the coal seams above 15 ft is preferred to be removed with stowing. About two thousand million tonnes of quality coal are estimated to be lying on pillars. Because of the inadequacy of sand, depillaring is not progressing fast. The result is that in some places a good deal of coal is likely to be lost. The country needs coal, but the production from depillaring is low. The Government of India is no doubt installing rope-ways to provide sand to the collieries for stowing purposes. Even so, the methods which are being applied in France, in conditions similar to those in India, are worth considering for our country. In India, the problem of inadequate supply of stowing material to mines, which is likely to become more acute with the growing demand for increased production, necessitates urgent action to be taken in this direction.

It is apparent from what has been stated in the previous paragraph that the introduction of longwall mining is a must if coal mining in India has to be carried out economically and with safety. Some work has already been done but what needs to be done is the introduction of longwall minings in certain groups of collieries in complete collaboration with Mining Research Stations and other research organizations and the major producers, preferably a public sector producer,

Research and Mining Industry

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Most of the mineral producing countries have research institutions for investigating special mining problems which face the industry from time to time. In India, the need has increasingly been realised over the years to conduct research into all the aspects of efficiency, safety and health in mines. To initiate and direct research into coal utilization and mining problems the Coal Mining Committee of 1937 and the Indian Coal-fields Committee of 1946 recommended the setting up of a 'Coal Research Board'. The Council of Scientific & Industrial Research appointed a committee to study a formal proposal for the establishment of a mining research station which was mooted out in 1948. The proposal to establish the Research Station was formally endorsed by the Ministry of Natural Resources and Scientific Research, the Ministry of Production, and the Ministry of Finance. The Research Station called 'Central Mining Research Station' thus came into existence towards the end of 1955.

The activities of the research station are divided into four main groups: (i) Mine Technology Group ; (ii) Mine Safety Group ; (iii) Mine Health Group ; (iv) Mine Engineering Group.

Here it is intended to discuss briefly some of the work being done in the Mining Technology Group of Central Mining Research Station. The research work of other groups will be discussed by other speakers of Central Mining Research Station.

The main objects of the research are :

(a) To improve productivity and safety in the existing mine workings.

(b) To evolve suitable methods of winning and working thick and/or inclined seams which can be safe in operation, give low production cost, give higher productivity and higher total production, and conserve the coal reserves.

Problems facing the mining industry

At present, in India, coal mining operation is not so efficient as can be seen that about 850 coal mines are producing 63 million tonnes of coal per annum with an overall O.M.S. (output per man shift) of 0.5 tonnes approximately. The productivity is still lower if open cast mines are excluded. This is rather discouraging if compared to some of the other countries. Thus, in UK, Germany, Poland and France the O.M.S. is

approximately 2¼ times that of India while in USA it is over 25 times. Thus one of the urgent needs is to increase productivity in Indian mines.

The bord and pillar system of mining is extensively used in India while in rare cases longwall system is practised. It has been generally felt that in India 40 to 50 per cent only of the coal reserve is extracted in mining for use. The rest of the coal is lost in mining operations. The reserves of metallurgical coal are low and stowing cannot be universally practised because of the nonavailability of stowing material or due to high cost of the operation. The total amount of coal reserve in India is 133, 486 million tonnes including proved, indicated and inferred reserves out of which 20,000 million tonnes have been proved. (*Resources and Qualities of Coals in India* by Majumdar, Santanu and Gupta, Sukumar ; *J. Min. Met. Fuels*, Special issue, 1964). Nearly half of the coal reserves are in the eastern part of the country from where about 80 per cent of the present production is obtained. Out of the total reserve non-coking bituminous coal accounts for 76.9 per cent and lignite accounts for 1.7 per cent.

Out of a total of 849 coal mines working in 1962–63, 120 mines used stowing, out of which 70 used hydraulic sand stowing, 3 hydraulic crushed stone stowing and 47 dry packing. Fifty mines used stowing for safety purposes and seventy mines for conservation. The total quantity of material stowed during the year was over 10 million tonnes and the ratio of coal raised to material stowed was 1 to 2.17 by weight.

There is, thus, a need for developing a system of mining thick and/or inclined seams without stowing but at the same time without losing more coal. If proper methods are not chosen, thick seam mining may give rise to dangers from spontaneous heating and fires. There is already a move to try methods of extracting thick seams without stowing in India in collaboration with foreign experts and indigenous talents. The CMRS has also been asked to collaborate in this trial.

Thick seam mining will involve working in lifts going upwards or coming downwards. In certain cases, there may be the possibility of leaving parting of coal in between lifts particularly in cases where inferior bands of coal or stone are available. For all these trials, CMRS is equipped to carry out scientific investigation about strata movement and loads on supports.

Due to the lack of suitable stowing material, or due to lack of sufficient quantity of water or due to the flatness of the seam it may not be possible to practice hydraulic stowing. Under these circumstances pneumatic stowing is worth trying. The CMRS has taken initiative to try pneumatic stowing in one of the mines of National Coal Development Corporation. The work will be conducted in collaboration with the Coal Board, National Coal Development Corporation and Office of the Chief Inspector of Mines. Another scheme for pneumatic stowing is being worked out by the CMRS.

It should be realized that the method of extraction has a great bearing on productivity, economics, transport and ventilation of a mine.

Deeper workings will have to be worked as shallow mines are exhausted. This will create special problems of strata control, rock pressure, bumps or bursts, heat, humidity, gassyness, dustiness etc. Gold mining in Kolar, where depths of over 3 km. have already reached, has already given a challenge to mining engineers as far as safety and working conditions are

concerned. Such problems are likely to be faced in coal mines also and at shallow depth than Kolar.

According to present indications, coal mining in India is visualized to be planned up to a depth of 1220 metres (4000 ft). On the basis of the work carried out by the CMRS the temperature of the rock at this depth in coal mine will be about 72°C. (161°F.). Suitable solutions of the problems associated with deep mining should be thought over well in advance.

Other problems associated with mining are mine fires aud subsidence. Since several years mine fire has been spreading in Jharia Coal-field. There seems to be danger to several inhabited places. These fires are mostly results of selective mining and bad planning. Opencast mining with reclamation and restoration of land would have avoided these dangers.

In his presidential address to the National Association of Colliery Managers (Indian Branch) in 1964 one of the present authors (K.N.S.) had suggested the formation of a National Opencast Coal Mining Corporation. "This Corporation may take over all areas it can possibly extract, with opencast mining by highly mechanised means on a large scale. This corporation should devote its attention exclusively to opencast mines and try its best to extend the field of operation to the maximum extent of its economic limit. With a view to ensure a fair deal and allow the corporation to extend to its maximum limit, all the various Government cesses and assistances should be pooled back or compensated to the output of this corporation. There may be even a very good case of extending special financial assistance for extending the field of operation of opencast mining in India. The idea of this corporation when given an honest and enthusiastic trial will go a long way in solving the problem of extraction of thick and concentrated seams at shallow depths. It will also raise the national average percentage of extraction. The cost of stowing, the price of conservation and safety could be pooled back to support the Opencast Coal Mining Corporation."

The other problem which is likely to be very important in the near future is that of Mine Subsidence. To extract coal under built up areas, under railways and other important places it is customary in India to leave coal in pillars. If comprehensive data are made available about the nature and magnitude of the surface movement it is possible to evolve a method of mining which will enable a complete extraction of the mineral without causing much damage to the surface property.

Intensive mechanization will create its own problem and this has got to be tackled in advance.

Research

The research work in the CMRS hns been planned to tackle all the above stated problems which the mining industry is likely to face in future. The operational research is being conducted to tackle the short term problems such as haulage, maintenance, timbering, etc. Several collieries have profited by the operational research which was conducted by the CMRS. To evolve incentive schemes operational research will prove to be of great benefit to the industry. Such work is being conducted by the CMRS.

In the Mining Technology Group, the research work in CMRS may be divided into three main categories, which may be divided further into the following branches.

Research work showing benefit in a short period—(i) Hydraulic Stowing, (ii) Operational Research, (iii) Roof Bolting, (iv) Assessment of the workability of coal, (v) Prediction of strata failure by microseismic detection.

Long term research—(i) Mine Subsidence, (ii) Strata Movement in longwall faces, (iii) Stability of mine pillars, (iv) Load on supports in underground workings, (v) Equivalent material model study, (vi) Strata movement in mine roadways, (vii) Pneumatic Stowing.

Fundamental research which may help to interpret the results—(i) Behaviour of rocks under compression, tension and shear, (ii) Anisotropic behaviour of rocks, (iii) Photoelastic model study.

Instrumentation to conduct research—Thus, research on mine workings is carried out in mines as well as in the laboratory.

Results

Results obtained from some of the investigations are described below briefly.

Hydraulic stowing.—In India, there are several shallow mines where stowing is carried out under low heads using high quantity of water compared to the amount of sand. To improve the stowing rate the mine management may not be prepared to make drastic alterations which may involve a great deal of expenditure. In one such mine, the improvements carried out by the Central Mining Research Station have enabled the stowing rate to be doubled (from 25 to 35 tons per hour to 70 to 90 tons per hour). In another mine, where the investigation is still continuing the rate of stowing in one mixing cone has increased from 14 tons per hour to 30 tons per hour. In both cases the water consumption per tonne of sand stowed has reduced considerably.

Roof bolting. The function of roof bolts is that the immediate weak roof can be suspended from a stronger formation above in which the bolt is anchored or several strata may be bolted together to form a strong stratum. Managements of several coal mines have approached CMRS to help them in selecting suitable lengths and pattern of bolting. In selecting the lengths of the bolts visual inspection of the strata section (near a fall) and the anchorage tests are taken into consideration. The anchorage tests gives the maximum load which can be taken by a bolt and this in turn guides the number of bolts to support a given area.

Tests have been conducted by CMRS in several mines. The results obtained in one mine are as under :

(i) Four feet long bolts have maximum anchorage capacity and minimum anchorage displacement for expansion-type and wedge type bolts. While the anchorage capacity varies from 23,000–27,000 lb. in both types of anchors, the average anchorage displacement for expansion type bolt is 0.006 in./1000 lb. and for wedge type bolt it is 0.003 in./1000 lb.

(ii) Installed loads of 8000–9000 lb. give better anchorage capacity and minimum anchorage displacement for expansion type bolts, while no definite relationship between the installed load and anchorage capacity could be established in wedge type bolts as the bolt installation was not standardized for lack of proper equipment.

(iii) Expansion type bolts have proved to be better than wedge type bolts in this particular shale strata.

Laboratory investigations have shown that during the first two hours, the rate of creep is high and after about 24 hr no further creep is noticed. A direct relationship between the loss of tension in the bolt and anchor creep is noticed. Investigations are being conducted to find the relationship between a range of different tensions and creep in the bolt.

Assessment of the workability of coal

Mechanical means of winning is becoming extremely necessary. In mechanical coal getting, proper knowledge on the strength characteristics of coal is essential. For this purpose, the strength characteristic of Indian coals is being investigated. For laboratory investigation following apparatuses are being used : (a) Impact strength index apparatus ; (b) Protoyakonov index apparatus ; (c) Coal penetration apparatus.

For underground tests coal penetrometer and expanding bolt seam tester will be used.

Strata movement in longwall faces

In a colliery in Jharia Coalfield strata movement measurement carried out on a 30 m. longwall retreating face using hydraulic sand stowing had shown the following :

(i) The first movement was detected in gate roadway by Electronic Convergence transmitter at a distance of 46.5 m. ahead of the face.

(ii) In the gate roadway the strata was found to undergo an oscillatory deformation—an increase in the amount of convergence followed by a certain amount of divergence.

(iii) Regarding the effect of coal cutting operation on the face convergence it was found that the effect was felt at the dip side of the face from the time the cutter was 6.6 m. ahead of the indicator to when the cutter was 7.8 m. behind the indicator (along the face line). The extent of the zone of disturbance at the midface was 6 m. ahead of the indicator to 7.2 m. behind the indicator, and at the rise side of the face it was from 3.5 m. ahead of the indicator to 3.6 m. behind it.

(iv) The magnitude of the convergence was found to vary from dip to rise side of the face.

(v) Very little lateral movement (2–3 mm.) has been noticed.

(vi) After every 30–35 m. face advance periodic maximum convergence was observed.

In a colliery in Raniganj Coalfield where a 72 m. longwall retreating face using caving system was being worked the following main points were observed :

(i) Periodicity in the occurrence of pronounced convergence has been observed after every 10–25 m. advance of the face. This interval was found to reduce as the distance of the face from its original position increased.

(ii) After every advance of 1.2 m., 2–4 m. of immediate roof caved in. But this was found to be prominent at only one half length of the face (towards conveyor gate).

(iii) No surface subsidence was observed although the area extracted was 80 m. × 150 m.

(iv) In the gate road convergence was noticed from the very first day when the instrument was set at a distance of 55 m. from the coal face.

Stability of mine pillars

For bord and pillar system, the Indian Coal Mines Regulations 1957, stipulate the minimum size of pillars and galleries for different depths. An important question arises as to what can be assumed as the life of the pillar. Scientific data concerning this are lacking. The coal pillars become the seat of certain abutment pressure due to their corresponding room spans and they usually adjust gradually by their slow deformation. The increasing load which is imposed due to mining operations also causes a slow flow of the bottom and/or top beds. Circumstances may arise when due to some reason or the other the pillars and surroundings become stressed beyond a safe limit. Now, if such areas can be recognized, we can project mining plans and operations to avoid such circumstances and in case these are unavoidable, to control the conditions as far as possible. The importance of the investigation lies in the fact that study of strain rates in and around pillars can reflect the stress conditions existing in the area. Instruments for measuring different types of movements are being fabricated in CMRS. Some of the results obtained by convergence recorders are given below.

In a colliery in Jharia Coalfield convergence measurements were carried out in 13 and 14 seams which are 6.6 m. and 8.4 m. thick respectively with an intervening parting of 1.8 m. thickness of shale. The 13 seam is at a depth of 158 m. at the pit. The size of pillars in both the seams are 30 m. × 12 m. Depillaring along with hydraulic stowing is being practised. The roof in both the seams are full of slips and comes down without any alarm. In this mine both convergence and divergence have been observed. The maximum total convergence recorded from a 13 seam recorder was 28 mm. in 14 days while the distance of the goaf edge reduced from 12 m. to 1.5 m. from the recorder. The maximum total convergence recorded from a 14 seam convergence recorder was 14.2 mm. in 14 days while the distance of the goaf edge reduced from 12 m. to 1.5 m. from the recorder. In 14 seam a convergence of 14.2 mm. occurred when the area of extraction (unstowed area) was 100 sq. m., and 4 mm. only when the area of extraction was 500 sq. m.

In another colliery in Jharia Coalfield where the workings were in 12 seam (7.3 m. thick) under a depth of 83 m. following points were observed :

From the measurements obtained, a general trend of increased convergence has been obtained starting from the first attack of stook till the withdrawal of the instrument and the convergence in the top section is at a lower magnitude than that of the bottom section. Examination of records for locations both in top and bottom section galleries show that the galleries are subjected to convergence and divergence periodically. A sudden high rate of daily convergence was indicated before an impending roof falls both in top and bottom section. During extraction by open caving system, at the first stage divergence is noted which may be due to the first splitting of pillars and the subsequent extraction of pillars from the boundary side in the panel and the bending action of the strata towards the boundary and relaxing the strata nearly the recorder.

First movement was detected between 15 m. and 20 m. ahead of the place of extraction. The least count of the measuring instrument was 0.5 mm.

Instrumentation

Instrumentation is the base for investigating the different problems which have been described in this paper. In the beginning few imported equipments were used. Main emphasis has been laid down on instrument design. This has led to design of 23 different types of instruments which can be used for measuring strata movement and support loads. One type of cage safety device to arrest cage in case of rope breakage has also been designed.

At present large quantities of yielding type props are being imported to equip longwall faces. To reduce the import of such equipments four types of friction props have been designed in CMRS. A list of all the equipments designed in Mining Technology Group of CMRS is given in Table 1.

The development of these instruments will save foreign exchange worth several lakhs of rupees.

Table 1—Instruments designed in Mining Technology Group

Sl No.	Patentee	Name of the devices
1.	Dr B. Singh	Electrical load cell of M-section
2.	do	Electrical load cell with curved surface
3.	do	Electrical roof bolt load cell of M-section
4.	do	Compression ring load cell
5.	do	Mechanical load cell uing a central lever and dial gauge
6.	do	Mechanical load cell using a peripheral lever and dial gauge
7.	do	Direct reading mechanical load cell
8.	do	Mechanical load cell of M-section using central lever
9.	do	Load cell incorporating roller extensometer
10.	do	Roof bolt load cell using lever
11.	do	Hydraulic load cell of M-section
12.	do	Direct reading load cell incorporating lever and roller
13.	do	Convergence indicator—rigid type
14.	do	Convergence indicator—suspension type
15.	do	Vernier convergence indicator—suspension type
16.	do	Improved type roller extensometer
17.	do	A sensitive device for the measurement of change in roof inclination (Clinometer)
18.	do	A device to be used as a Clinometer and also as an Extensometer
19.	do	An electrical borehole device for the measurement of bed slip in strata
20.	do	Extensometer
21.	do	Triple borehole extensometer
22.	Dr B. Singh & Dr K.N. Sinha	Convergence recorder
23.	Dr B. Singh & Shri R.K. Prasad	Cage safety device
24.	do	Load cell incorporating an optical device
25.	Dr B. Singh & Shri N.C. Saxena	Friction prop with 'V' type friction wedges incorporating four friction surfaces (Three designs)
26.	do	Friction prop incorporating three friction surfaces (Three designs)
27.	do	Friction prop with four friction surfaces and bracket clamps

Conclusion

In this brief article, an attempt has been made to bring out some of the salient points of the investigation which are being conducted by the Mining Technology Group of Central Mining Research Station to help the mining industry. This work will lead to increased safety and efficiency in mines which in turn will increase productivity.

Colliery Mechanization

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Before embarking on mechanization, a survey must be made with regard to the availability of equipment manufactured in this country, spare parts, and training facilities for the personnel to operate, maintain and repair the machines. Unless adequate thought is given to these points wrong policies could be implemented which may prove injurious to the future of the mining industry. Only through success can mechanization spread horizontally and vertically throughout the industry.

Scope for mechanization

One of the most important factors in the process of mechanization is to find out what should be the sequence of mechanization—in other words what process should be given preference and up to what degree it should be mechanized to get the maximum efficiency out of the mechanization.

In the Mining Industry there are several fields for mechanization, e.g. the coal face, transport both on the surface and underground, pit-top and pit-bottom layouts, the marshalling yards, loading of coal in the mainline railway wagons, storage of coal, etc.

If the mechanization is not phased out properly with due care then there is a real danger of deriving adverse conclusions from mechanization. Therefore, a proper survey by work and motion study teams will reveal useful and necessary information to start mechanizing. For example, mechanization at the coal face and of transport should be phased out in such a way that a higher production at the coal face is efficiently and effectively handled by the transport system.

At the same time the coal face workers should not be wasting their time for lack of availability of empty trains.

In some of our small collieries the introduction of mechanization to pump out the water from the colliery will raise the output and the productivity of the mine. In such collieries it has been noticed that when the miners go down the pit in the morning and find the coal face is full of water and therefore they first have to clear the water and then start extracting the coal. Thus, this is an important aspect of mechanization.

Coal face mechanization

The mechanization of a coal face does not necessarily mean a coal cutter and loader machine or hydraulic props and chokes or a manless face as has

been recently practised in European and American mines. In Indian conditions, coal face mechanization may be programmed quite differently. In our conditions, a coal face could be said to be well mechanized if it has a coal cutter to give under cuts, mechanical drills to drill the holes and blasted by explosives and finally hand loaded in tubs or onto conveyors. Even today, 40 per cent of the British coal is being obtained by this method. This type of mechanization will have the following advantages:

(i) Less costly to equip, since only machines used will be the coal cutter and the drill.

(ii) More experienced workers are available who can operate the machines and drill the holes.

(iii) The machines are easier to operate and less training is required.

(iv) The necessary number of machines could be manufactured in the country with our own know-how and materials, hence no dependence on foreign countries.

(v) Spare parts can be made available quickly which will require less time for the repair and overhaul work of these machines.

Recently the author visited a coal mine in the Jharia coalfield ; it is interesting to note these facts in connection with the colliery :

Output : 18,000 – 20,000 tons per month, i.e. about a quarter of a million tones per head.

Manpower : 1,100 – 1,200.

Mechanization : Only pumping and rope haulage.

But this colliery has started coal cutting and blasting on an experimental basis.

A colliery producing quarter of a million tons per year is a big colliery and it is difficult to believe that it has no mechanized face. This colliery is considering mechanization in the way discussed above and will definitely increase the output tremendously. It is worth keeping an eye on the mechanization and productivity of such collieries which will give us considerable practical experience for our type of mechanization.

Transport mechanization

Transport is a vital link in the production chain of any industry. The coal face cannot be mechanized in isolation from the transport which has to take the product of face mechanization to the consumers, but here only underground and surface transport at the mine will be discussed.

The colliery transport system must be adequately mechanized to meet the increased production at the coal face. There are several types of transport systems and the best has to be selected to suit the conditions of the individual mines keeping the cost and performance in mind. Selection could be made from :

(i) Rope haulage, (ii) conveyor, (iii) locomotives and, (iv) hydraulic transport.

Rope haulage. The rope haulage system for underground and surface transportation of coal has been widely used in Indian mines for many years. Enough knowledge is available through practical experience and a properly planned rope haulage system will give the maximum yield provided it is worked and maintained efficiently and break down services rendered

quickly. At present, rope haulage is dealing with the output of our big mines quite efficiently and in many of our small mines quick results will show with this system of transportation.

Conveyor. There are different types of conveyors, e.g. belt conveyor, rope belt conveyors, chain conveyors and plate conveyors, but the author restricts himself to belt conveyor. This is being used increasingly in coal mines in foreign countries and has mostly replaced the rope haulages in British coal mines. It is a continuous process of transportation and can deal adequately with quite a high output. But in our mines, we can introduce belt conveyor slowly gaining the experience and equipping ourselves as we progress.

Locomotives. Locomotive transportation is very flexible and wherever possible, especially in big mines, the locomotive transportation should be introduced on the surface and if conditions permit, also underground. This system of transportation is being used in some of our big mines and is showing a very good return.

In foreign countries, locomotive transport system is being preferred to any other due to its speed and manoeuvrability, the selection of locomotives being any of the following types : Electric locomotive, Diesel electric and Battery locomotive.

The selection of the type of locomotive depends upon several factors : If to be used underground or on the surface, availability of the locomotive, availability of power, hauling distance and the gassiness of the mine.

In general, in Indian conditions, the selection could be made for diesel locomotives which is more flexible than overhead trolley locomotive since it is independent of any overhead lines and is also independent of any battery charging system ; though trolley wire electric locomotive is also used in a few mines both on the surface and underground, and giving very good dividend. Battery locomotive may be useful for short distance shunting work but it has the drawback of needing a battery charging station, especially if it has to be used underground.

Hydraulic transport. Since a water problem is met with in most of our collieries, a transportation of coal by hydraulic medium will be worth investigation, a problem which could be investigated in collaboration with the Central Mining Research Station. This system of transportation will also solve the water pumping problems in mines.

Some research work has been done in this line in foreign countries but here it has not yet received attention. This method of transport may prove economically cheaper than other methods where it is applicable.

Ventilation

So long as the working is near the surface and not far from the shaft, one could depend on natural ventilation. But as the working goes deeper from the surface and further away from the shaft bottom, the ventilation problems increase. Men working underground must get the right quality and quantity of air supplied at the right temperature and to achieve this mechanical means are required to supply the air to the working faces. Only long term planning considering the life and layout of the mine and the output could give proper results. The proper type of fan must be selected to supply the desired air for most of the period of the life of the mine with the highest efficiency.

Ventilation planning is one of the important parts of mining and must be given due consideration. Here the Central Mining Research Station may prove very useful and their experience should be sought.

Mining lighting

Lighting systems in most of the collieries is poor which affects the working capacity and hence the efficiency of the miners, especially the coal face worker. Proper attention should be given to this problem. But here a self equipped electric lighting unit for underground work will be most useful since it would not need any cables etc. for the transmission of electrical power. Such a lighting unit may not be available in the market and our Research Station will be an asset to design one which would suit the requirements of our mines.

Water pumping

Adequate pumping facilities in all the mines will immensely increase the output and the productivity of the mining industry. Our mine managers must stress this point and should give priority to it.

These are some of the important items which we have to tackle first.

Since most of the conditions of mines in India and in the USA are similar, it may prove useful to know the process of mechanization of mines in USA.

Process of mechanization in USA

In America where seams are thick and level measures, the locomotive haulage was particularly suited. The pillar and stall methods were ideal in USA with shallow depth and strong unfractured strata. Therefore, this was and is by far the most widely adopted method of work and machinery has been developed accordingly. The mechanization was introduced in the following stages.

Cutting of coal and haulage. The coal was undercut with short wall machinery or arc sheerer, fired with explosives and hand filled into tubs or mine cars. The cars were shunted into the working places by small trolley wire locomotives, and taken out on to the main haulage where they were picked up by mainline locomotives and taken to the pit-bottom or mine entrance.

Loading. The loading was mechanized where Joy Load directly loaded the coal into mine cars.

Transport. The introduction of rubber tyred vehicles below ground obsoleted track laying with all its attendants, restrictions and discordants. This was a big breakthrough in the American mechanization of the coal mines. This made the operations on the working face more flexible and rapid and paved the way for future developments.

Flexibility. To make the cutting, boring and roof bolting machinery more flexible and rapid, they were mounted on rubber tyres.

Belt conveying. Further mechanization came in the transport section with belt conveying.

Continuous miners. The introduction of continous miners in room and pillar working is a major development. These continuous miners are

crawler mounted and mine their way into the coal. Some have very high capacity, e.g. the Joy Twin Borer can mine at a rate of 8 tons per minute. The main problem with these machines is that of getting the coal away from them. The machines dump the coal behind them and a Joy loader delivers to shuttle cars. Alternatively, the continuous miners can operate with an extensible conveyor, or a system of shunt shuttle conveyor. During development work the output would be about 400 tons and 500 tons during extraction of pillers. There are usually 8 men in a continuous miner team.

Secondary haulage in American mines

Another important point to note in the American mines is the ease and speed with which men and materials can be transported underground. The men are usually carried from the shaft side to the working section in section cars run by trolley wire locomotive. There are self propelled vehicles and can accommodate the whole section crew. Jeeps and small trolley-wire vehicles, are available for the senior officials at the mine.

Conclusion

Mechanization is a must for the Indian mining industry for increased productivity. Only machanization coupled with the efficiency to operate this system will give us a position in the competitive world market. The success of the mechanization will largely depend upon the following factors :

(i) How best our management re-organizes itself to cope with the new ideas of mechanization.

(ii) How best our labour force could be trained for the changing conditions of work.

(iii) How we plan our maintenance and general repair team and what their efficiency is. The efficiency of the maintenance and repair will largely depend upon the availability of the parts and the skill of our personnel.

(iv) The support of the union is one of the important factors in the success of mechanization. We must get the full cooperation from the unions.

The Research Station would be of great help in this direction. A good production chart should be made and results compared with the estimated value in order to get the maximum from mechanization.

A Broad Assessment of India's Mineral Position*

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This paper is intended to be a bird's-eye view of India's status in minerals, ores, metals and alloys. The data published by the Indian Bureau of Mines (Indian Minerals Handbook 1962, Survey of India's Foreign Mineral Markets, Monthly Bulletins of Mineral Statistics) reveal an alarming deficit of trade balance in this field. This is due partly to inadequate production and partly to lack of suitable metallurgical plants. While some ores are exported by India, their metals and alloys are purchased back at much higher prices. Liquidation of the deficit, therefore, is not merely a problem of producing more minerals and ores, but it is also one of simultaneous development of adequate metallurgical know-how and capacity and other ancillary facilities including transportation and port.

It will be seen that, in order to produce the necessary quantity of minerals and ores within the country, a very substantial increase is immediately necessary in the efforts of exploration, prospecting and mines development. Appropriate emphasis needs to be given to the application of all likely techniques, integrated examination of all available data and applied research towards methodology and design and construction of instruments.

Annual production

The total value of production of minerals and ores in India, excluding fuel and atomic minerals, during 1956–64 is shown in Table 1.

Table 1—Value of mineral production during 1956-64

(Rs millions)

	Metallic			Non-metallic	Total
	Ferrous	Non-ferrous	Total		
1956	171	110	281	137	418
1957	187	100	287	192	479
1958	167	98	265	219	484
1959	155	101	256	226	482
1960	179	106	285	271	556
1961	168	103	271	351	622
1962	170	105	275	428	703
1963	225	86	311	287	598
1964	217	90	307	243	550

*Excluding fuel and atomic minerals.

It will be seen that the years 1963 and 1964 witnessed falls in mineral production to the extent of 15 and 8 per cent respectively as compared to the preceeding years 1962 and 1963. The fall in 1964 as compared to that in 1962 is over 21 per cent. It is true that the total mineral production value depends not only on the quantity of minerals produced, but also on the prevalent prices of the various minerals. However, the individual variation in prices is somewhat smoothed out in the overall picture, and any rise or fall in the total annual value of production does in general indicate a corresponding trend in the output tonnage as well. For instance, the drop of Rs 48 million from 1963 to 1964 was partly due to a fall in the price of salt and partly due to a fall in the outputs of dolomite (by Rs 6·1 million), iron ore (by Rs 4.4 million), mica (by Rs 3.8 million), chromite (by Rs 2.2 million), and other minerals.

Import and export comparison

Table 2 summarizes the overall position of India's trade balance in minerals, ores, metals and alloys.

The trade balance in minerals and ores fell precariously between 1956 and 1962 due to intreased imports and sluggish exports. Although the imports still kept rising, the years 1963 and 1964 saw an improved export position with a consequent recovery in trade balance (Table 2). It is hoped this trend continues. The positive trade balance is, however, somewhat illusory in the sense that it does not take into account the imports made by India by way of metals and alloys, for which the ores and minerals constitute the raw materials. The latter, shown in Table 2, presents a dismal picture. Thus, in the final analysis, the annual drain of the country's foreign exchange in the overall field of minerals, ores, metals and alloys is of the order of Rs 1000 millions. It becomes immediately obvious that it is not only necessary to explore for and locate new reserves of minerals and ores (especially those that we import), but it is also of paramount importance to acquire and establish the technology required for processing the minerals and ores into the metals and alloys.

Target of production

Ideally speaking, India should produce enough minerals and ores to cover the following requirements: (a) Promotion of exports of minerals and ores; (b) Elimination of import of minerals and ores; (c) Elimination of import of metals and alloys. This, as mentioned earlier, requires simultaneous setting up of suitable processing plants; (d) promotion of export of metals and alloys; and (e) Growing indigenous consumption.

Table 2—Comparison of exports and imports in minerals, ores, metals and alloys

(Rs millions)

	Export (minerals & ores)	Import (minerals & ores)	Trade balance (minerals & ores)	Trade balance (metals & alloys)
1956	487	97	+390	—
1957	601	94	+507	—
1958	407	80	+327	—1209
1959	423	102	+321	—1157
1960	472	108	+364	—1435
1961	440	111	+329	—1296
1962	419	149	+270	—1355
1963	580	168	+412	—1321
1964	735	165	+570	—1148

Table 3—Yearwise mineral/ore production

(Rs millions)

	Export (minerals & ores)	Import (minerals & ores)	Import (metals & alloys)	Export (metals & alloys)	Indigenous consumption (minerals & ores)
	(a)	(b)	(c)	(d)	(e)
1956	487	98	—	—	—
1957	601	94	—	—	—
1958	407	80	1328	119	—
1959	423	102	1230	73	—
1960	472	108	1578	145	—
1961	440	111	1490	194	—
1962	419	149	1405	50	—
1963	580	158	1407	86	438
1964	735	165	1618	170	390
1965*	875	172	1600	100	450
1970*	1200	205	2000	200	700
1980*	1600	275	2500	300	1200

*Estimates (considered conservative)

Table 3 shows the year-wise valuation under the above five items. The figures for 1965, 1970 and 1980 are estimates, considered conservative, based on the present trend.

These figures are evidently very approximate and are intended only to indicate the magnitude of the problem. Moreover, the figures in Tables 1 to 3 are not directly comparable, since the pricing differs greatly in computing annual production, imports and exports. The annual production is computed on the basis of the pit's mouth value, the export valuation is based on f.o.b. rates at various ports including export duty where applicable, and the import valuation uses the c.i.f. value.

The figures [Table 3, col. (c)] have been arrived at in the following way. From the available mineralwise tonnage details for production and export for the years 1963 and 1964, the proportion of various minerals exported was valued at the pit's mouth rate and summed. These two values (for 1963 and 1964) were subtracted from the total production figures for 1963 and 1964 to arrive at the internal consumption of minerals and ores. For both these years, it turned out that the pit's mouth values of the total exports are of the order of Rs 160 millions. For 1965, 1970 and 1980, the values are extrapolations and it is hoped that they will represent the order of magnitude.

As stated earlier, the ideal aim is to produce in India all the material implied in Table 3. This means that we should try to arrive at a target figure (at the pit's mouth rate) for production of minerals and ores, that would ensure an adequate supply of raw materials to produce what all is indicated by Table 3. A reduction of the figures of Table 3 to a common base, namely mineral/ore production at pit's mouth rate, is called for.

Such a reduction, which is difficult and certainly subjective to a great extent, has been attempted in Table 4. The underlying assumptions, which are explained in the next paragraph, can be a matter of opinion, and therefore, the figures in Table 4 are at best qualitative in nature. It would be adequate if the figures represent the order of magnitude correctly.

Table 4—Valuation of mineral/ore required to be produced

(Rs millions)

	Export (minerals ores) (a)	Import substitution (minerals & ores) (b)	Import substitution metals & alloys) (c)	Export (metals alloys) (d)	Internal consumption (e)	Total	Present production
1963	160	40	281	17	438	936	598
1964	160	41	324	34	390	949	550
1965	219	43	320	20	450	1052	—
1970	300	51	400	40	700	1491	—
1980	400	69	500	60	1200	2229	—

It has been already stated that the total export of minerals and ores for 1963 and 1964, valued at the pit's mouth rate, stands at Rs 160 million approximately per year. The remaining figures in col. (a) of Table 4 have been arrived at by reducing the corresponding figures of Table 3 in the same proportion (factor of 0.25). Assuming that export and import pricings are similar, the same factor has been applied to obtain col. (b) in Table 3. The reduction of the next two columns involving metals and alloys is rather arbitrary and the factor of 0.20 have been applied to them.

Table 4, which is admittedly imprecise, does make one point clear. If India is to strive to do away with imports and promote exports in the field of minerals and ores (including metals and alloys), the overall production of minerals and ores must immediately increase by at least 50 to 100 per cent. The intensification of efforts (in terms of exploration and prospecting for minerals and ores, and development of mines) necessary for this extra production may as well be twice as much—between 100 and 200 per cent.

It needs re-emphasis that a unilateral increase in the mineral output, essential as it is, will not by itself erase the huge trade deficit mentioned earlier. Metallurgical plants capable of producing the metals and alloys from the minerals and ores produced in the country must be simultaneously erected. It is instructive to recall, for instance, that while India exports iron ore to the tune of Rs 370 million per year, it spends about Rs 1000 million in foreign exchange annually to purchase various kinds of ferro-alloys, pig iron, sponge, iron and other iron and steel materials. Similarly, while three to four million rupees worth of bauxite is exported annually, a fabulous sum of about Rs 68 million in foreign exchange is spent annually to buy back metallic aluminium. Apart from setting up metallurgical plants, adequate transportation and port facilities must also be developed at the same time.

Priority minerals

In our search for and production of minerals and ores, the priority should relate directly to import. Considering the valuation of the raw minerals and ores that are imported, one arrives at the following priority list: sulphur, apatite (rock phosphates), asbestos, emerald, borax, abrasives, gypsum, antimony ore, diamond, cryolite, sodium nitrate, graphite, and so on. At the same time, from the point of view of metal imports, the order of importance is: copper, zinc, tin, lead, nickel, platinum and others. These two lists give a clear idea as to what minerals and ores we should be looking for.

It is indeed likely that not all the minerals and ores referred to above can be produced in India to the extent desired, because of a paucity of adequate deposits. Sulphur, for instance, which tops one of the priority lists, has only a scanty occurrence in India. In the native state, its occurrence has been reported from the Andamans, Krishna and Godavari in Andhra Pradesh, Kangra in Punjab, coal measures of M.P. and Gharwal in U.P. As a sulphide (pyrite), it is known to occur in many places including Tandur, Kothagudem and Sasti in A.P., Amjor and Rohtas in Bihar, Simla in Punjab, Polur and Wynad in Madras, Inghaldal in Mysore, Matiana in Himachal Pradesh and Almora in U.P. Though most of these occurrences are reported to be poor and uneconomical, it is necessary to re-examine and re-explore these areas thoroughly using all possible methods. Exploration methods—geological, geophysical and geochemical—have developed greatly in recent years, and the use of these modern techniques is called for, wherever applicable. Deposits of various kinds of copper ore, which tops the other priority list, are numerous in India although the quality of the ores are in general low. Chalcopyrite (Cu_6FeS_2) occurs in Singhbhum district in Bihar, Khetri Copper Belt, Alwar, Jaipur and Sikar districts in Rajasthan, Sikkim, Agnigundla belt, Mailaram, Gani Belt, Garimanipenta in A.P., South Arcot district in Madras, Chitaldrug and Hassan districts Mysore, Bastar District in MP, Almora, Pithorgarh and Gharwal Districts in U.P., and some other places. Other forms of copper ore— malachite, azurite, covellite, bornite and chalcocite—have also been reported from a number of places.

Without going into such details for the other minerals and ores on the priority lists, it can perhaps be safely said that the overall position of mineral occurrences in India holds good promise, if taken up with the seriousness that the situation urgently demands.

In formulating an effective exploration policy, two points of view need to be considered. One is to search directly for specific minerals and ores, wherever they may occur, in the order of priority set by the import valuations. This approach suggests itself in view of the immediate needs of higher production, The other is to begin by systematically studying mineralized provinces on a regional scale and then going in suitable steps to detailed investigations. The latter approach, of course, leads to a sounder understanding of the province as a whole—the structural and stratigraphic controls, the geochemical environment, the minerogenetic trends etc. Since the country's immediate demands must be met and at the same time a scientific development of the natural resources must be assured, it seems obvious that both these approaches have to be adopted and followed simultaneously. That is, while some of the priority minerals should be looked for directly, some of the mineral-rich regions must also be studied systematically using all available tools.

Geological appraisal

This section is a brief outline of the mineral-rich provinces in India, referred to in the preceeding paragraph. Keeping in view the general geology and stratigraphy of peninsular and extrapeninsular areas, six areas have been outlined as shown in Fig. 1. The areas are Dharwar, Cuddapah Basin and Eastern Ghats, Satpura, Aravalli, Assam Plateau and Himalayas. It is significant to note that the areas where the different orogenic trends meet form regions of critical interest, and show development of a host of mineralogical associations. Such critical areas are south-eastern Gujarat State, Singhbhum and north Chhote Nagpur areas of Bihar, Godavari valley fringes of A.P. and Kerala State. As indicated already, integrated

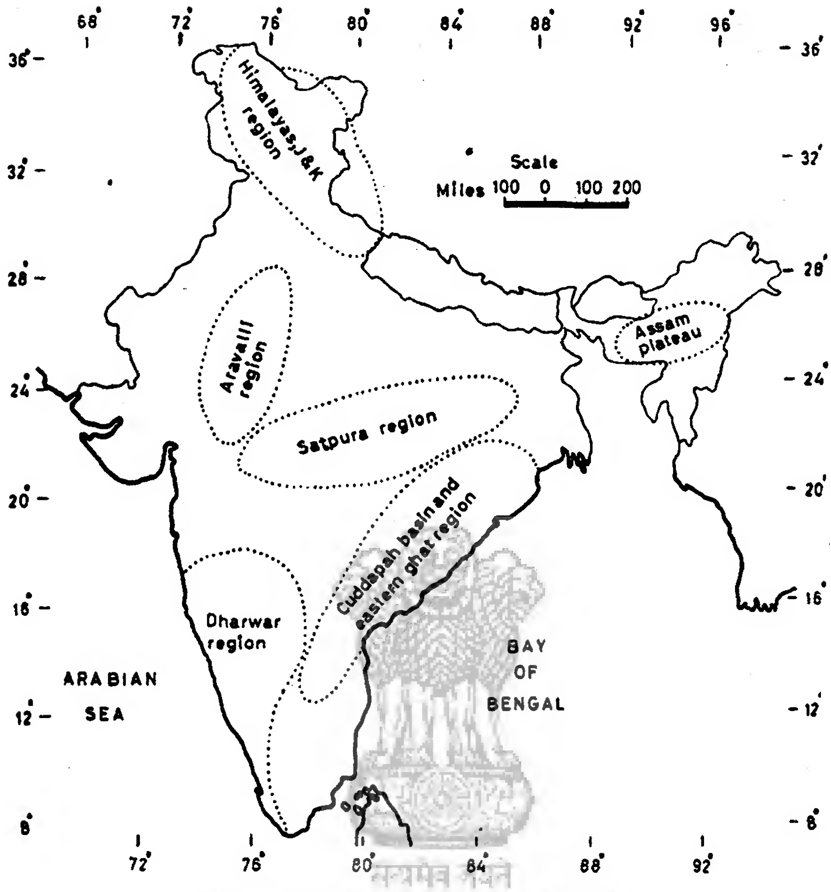


FIG. 1—MAP SHOWING CRITICAL REGIONS

studies in these regions using disciplines of geology, geophysics and geochemistry should increase our understanding of relationship of mineralization of lithology, structures, and physicochemical factors.

These investigations in turn will help in locating board areas where intensive search for economic mineral deposits should be concentrated.

Dharwar region. The Dharwar area as discussed here includes Mysore, Madras, Kerala and part of A.P. The rock formations comprise chlorite and hronblende schists, ferruginous cherts, gneisses, granites, charnockites, basic and ultrabasic intrusives of Precambrian age. The general strike of the formations is NW.-SE. changing in the southern portion to NNE.-SSW. along the Eastern Ghats. These Archaean rocks embody most of the following important economic minerals and ores.

Iron ore bodies are mainly associated with the banded hematite and magnetite beds occurring at marker horizons in the Dharwarian schist belt. The iron ore areas are Babadudan, Bellary, Hospet, Sandur, Kudremukha-Gangamula and Shimoga of Mysore, and Kayamalai, Tiruthamalai, Kallamalai, Tiruchirapally, etc., of Madras state.

Manganese ores are found in association with magnetite quartzite horizons and as pockets in Dharwar schists. It is found in Shimoga,

Bellary, Usoda, Nogi Chyoli and Sandur areas of Mysore and Srikakulam and Garividi of A.P.

Chromite occurs as pockets, layers and lenses in the ultrabasic intrusives of Archaean age. It occurs in Hassan, Arsikere, Hosdurga, Niggihalli, Gunur and Chitaldrug areas of Mysore, Salem in Madras and Warangal and Kondapalli areas of A.P.

Ilmenite occurs in the beach sands of south Kerala and the east coast. The areas in the western coast are Nindakera, Quilon. Anjingo, Warkara, Kovillam, etc.

Bauxite deposits occur as capping on Deccan Trap lavas and peninsular gneisses, and as alluvial covers on the west coast of Mysore. The areas are Shevroy Hills of Madras, west coast in Kerala and Mysore, and northern districts of Mysore.

Copper ore occurs in Archaean geneisses and schists as thin streaks, veins and lenses. Important occurrences are Ingaldhal, Nanjangud, Kalyadi, Tathni in Mysore, and Mamamdur in Madras.

Gold and Silver occur in schists belt of Kolar in association with quartz lenses and veins. The other occurrence is the Hutti Gold mines of A.P. Silver occurs in association with gold and also with sulphides of Cu, Pb, and Zn at several places.

Lead and Zinc occurrences are known at Nanjangud and Chitaldrug areas of Mysore.

Mica occurs in pegmatites traversing the mica schist of Archaean age. The important areas are along the 100 km. long mica belt along Gudur, Sargam, Rapur, Podalpur, Atmapur, and Kavali in Nellore districts in A.P. Other areas are Neyoor and Ponalur in Kerala.

Magnesite is found as alteration products of magnesium silicate rocks (Dunite) occurring as intrusive bodies in gneisses at Salem of Madras.

Phosphate nodules occur in limestone and shales of Utatur stage belonging to Cretaceous system. The areas are Utatur and Dalmiapuram.

Asbestos pockets occur in ultrabasic intrusives in Hassan and Mysore districts of Mysore.

Cuddapah basin and Eastern Ghats region. The region as discussed here, includes parts of Orissa, Madhya Pradesh, Andhra Pradesh and Madras. The Cuddapah basin in Andhra Pradesh has a crescentic shape, its concave side facing the east and being about 340 km. long. The basin is occupied by limestones, quartzites, shales, sandstones and basic intrusives belonging to Cuddapah and Kurnool systems. The Eastern Ghats stretch from the Nilgiris in the southwest to the border of Orissa and Bengal exhibiting a general NE.-SW. strike. This strike meets Mahanadi strike (NW.-SE.) in between Godavari and Mahanadi rivers. In Singhbhum it meets with Satpura strike (ENE.-WSW.). The Eastern Ghats comprise Archaean gneisses, schists, khondalites, quarzites and calcgranulites.

Important economic minerals found in this region are discussed below:

Large deposits of crysotile asbestos are found in Vempalle limestone at the contact of basic sills. At times, the asbestos zones attain a thickness

of about 1 metre. The best deposits are found about 5 to 10 km. west of Pulivendla in Cuddapah district.

Chromite occurs in basic intrusives in Archaean rocks at Cuttack and Dhenkanal in Orissa, and Kondapalli in Krishna district of Andhra Pradesh.

Copper is found in Dharwarian schists at Agnigundala and Garimenapenta and in Cuddapah rocks at Gani.

Mica has been described under Dharwar region.

Lead ore is found associated with the sulphide mineralization at Agnigundala, and several places in Cuddapah basin.

Manganese ore is found associated with khondalites and kodurites in Ganjam, Koraput of Orissa and Visakhapatnam and Orissa coast.

Low grade iron ore is found as thin pockets in Kurnool sandstone. It is locally worked out on small scale.

Some bauxite-laterite cappings are found in Karalpat, Kasipur and Mahulpatna in Kalahandi district of Orissa.

Workable deposits of graphite occur in the khondalite and associated gneisses of Kalahandi, Bolangir, Ganjam and Koraput in Orissa and Visakhapatnam and Godavari districts of Andhra Pradesh.

Important barytes deposits occur as veins in Vempalle limestone at Vempalle, Pulivendla, Kotapalle, Nerijumapalle, Mutssukota and Balapalapalle in Cuddapah basin.

Satpura region. The Satpura region covers parts of Bihar, Orissa and Madhya Pradesh. Nagpur, Bhandra, Chindwara, Chhota Nagpur plateu, Ranchi plateau, Koenjhar and Gaya regions contain many important, economic minerals. The general strike of rocks in the region is NE.-SW, changing to E.-W. in western part. In the eastern part of the region at north Singhbhum, the NE.-SW. Satpura strike meets the NNE.-SSW. strike of Eastern Ghats.

Some of the more important economic minerals found in this region are mentioned below:

Large deposits of iron ore are found in Singhbhum, Mayurbhanj, Koenjhar, Bonai and other places. The total reserves of sedimentary iron ore are more then 8000 million tons in Singhbhum area alone.

Manganese ore is found in several places in this region, mainly in Kolhan and Singhbhum in Bihar, and in Jhabua state, Balaghat, Bhandara, Chindwara and Nagpur districts of Madhya Pradesh and Maharashtra.

Copper ore is found at various places in Singhbhum, Nagpur and certain other places like Bhagalpur, Palamau and Santhal Paragana districts. Singhbhum copper belt extends from Duarpuram in the west through Kharsawan, Rajgadh, Rakha mines, and Mosabani upto Bhargora in the east, a distance of 130 km.

Chromite deposits associated with ultrabasic rocks are found in Singhbhum and Koenjhar in this region.

Bauxite is found in Ranchi and Palamau districts of Bihar, Surguja, Raipur, Bilaspur, Balaghat, etc. in Madhya Pradesh and Kalahandi and Sambalpur in Orissa.

Some occurrences of Wolfram have been reported from Singhbhum and Nagpur.

Aravalli region. Aravalli region here includes Rajasthan, Gujarat, and parts, of U.P. and M.P. The chief rock formations are phyllites, quartzites, chlorite-mica schists, hornblende schists, limestone, granites gneisses and various basic and ultrabasic intrusives of Aravalli and Delhi systems. The general strike of the formations is NE.-SW. In eastern and southern Gujarat, the strike becomes NW.-SE. This meeting point of the two strikes lies in Gujarat state and is important since some of the important ore producing areas lie in this region.

The important economic minerals found in the area are discussed below.

Iron ore is found as pockets in hematite quartzites of Aravalli systems in Lahara and Pipalgaon in Rajasthan.

Manganese occurs as pockets and bands in Aravalli rocks in Punchmahal area of Gujarat, and Banswara and Udaipur districts of Rajasthan.

Bauxite occurs as capping on gneisses and basic flows in Bikaner, Kotta and Tonk districts of Rajasthan state.

Copper ore lodes occur along a 80 km. long mineralized belt running approximately N-S, along Singhana and Babai areas in Jaipur district. The ore occurs in Chlorite-quartz schist as thin streaks lenses and veins. The other area is Dariba.

Lead and Zinc occur in Zawar area in Udaipur district as replacement veins and fissure fillings in dolomite of Aravallis. The other areas are Punchmahal, Baroda and Surat districts of Gujarat.

Silver is associated with the lead-zinc ores of Zawar.

Mica occurs in pegmatites of Jaipur, Ajmer, Merwara, Kishengarh and Bhilwara districts of Rajasthan.

Asbestos occurs as small veins in basic intrusives in Ajmer and Merwar districts of Rajasthan.

Assam plateau. The Assam plateau comprises the Garro, Khasi and Jaintia hills, and the detached area of the Mikir hills in the north-east. The Archeans are represented by gneisses, schists, granites and Shillong series which is composed of quartzites, conglomerates, phyllites, sericites, chlorite, mica and horn-blende schists. Copper is found at Gauhati, Sisi valley, and Potin. No other mineral of importance seems to have been reported from Assam plateau.

Himalayas, Jammu & Kashmir. This region includes Himalayan ranges in U.P., Punjab, Himachal Pradesh, Jammu & Kashmir. The general strike of rock formations is WNW.-ESE. becoming NW.-SE. in Kashmir and Ladakh areas. It comprises metamorphic and sedimentary rocks varying in age from Precambrian to Pleistocene, intruded by various igneous rocks of different ages. Four successive thrust zones are found in south to north traverse from Gangetic plains to main Himalayas. A few areas only are known to be of some economic importance. A lot of detailed geological and prospecting work is needed to explore the mineral riches of Himalayas.

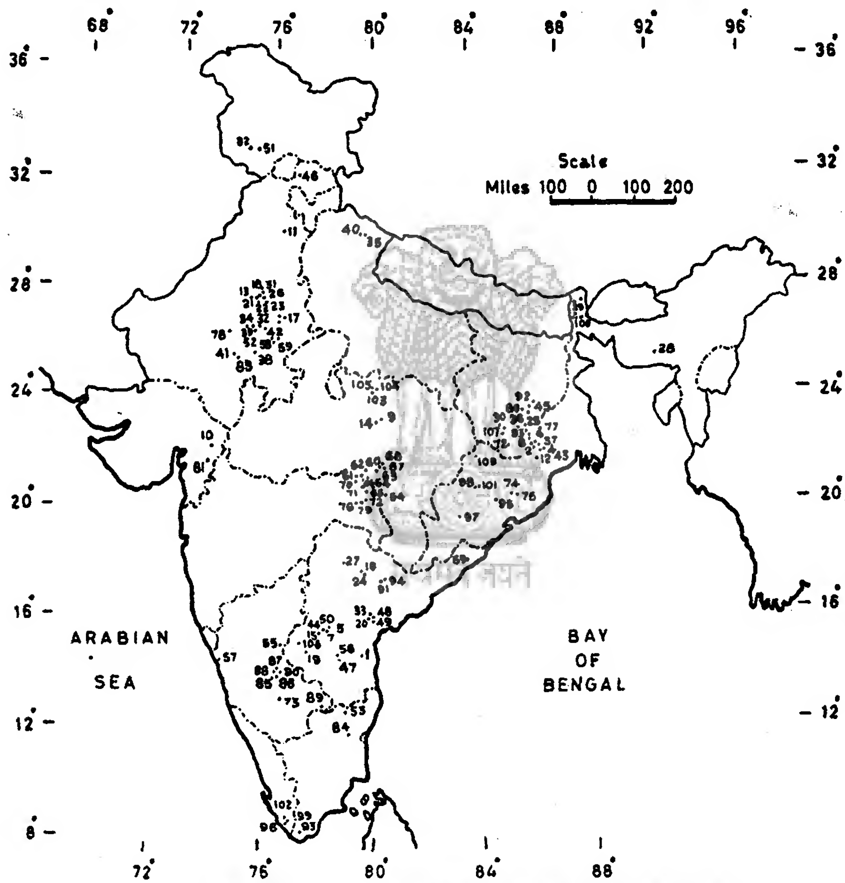
Some of the important minerals produced in this region are as follows:

Copper ore occurs in Precambrian schistose formations at Dhanpur, Pokhir and Askot in Almora and Garhwal in U.P.

Small magnesite deposits are found in Garhwal nappe rocks in Almora district.

total of about 200 geophysical investigations, ...
minerals and ores (excluding mineral fuels), Gravity, magnetic, electrical and electromagnetic methods have been used for manganese, chromite, copper, lead and zinc, diamond, graphite, tungsten, wolfram, fluorite, vermiculite, china clay and limestone. The location map of these 108 parties is shown in Fig. 2 (by Goeological Survey of India) which should be seen along with the Appendix for name of area, method used and mineral surveyed for. Notably good results have been obtained in regard to manganese, sulphide ores, chromium, and location of volcanic necks.

The National Geophysical Research Institute has a small group of workers capable of dealing with problems relating to exploration, especially geophysical exploration. A small amount of reconnaissance type of geophysical work has been done by NGRI at Khetri for copper and at Kudremukha



GEOPHYSICAL SURVEYS FOR MINERALS AND ORES

for iron ore at the request of National Mineral Development Corporation. Recently, a geophysical party has been sent to Orissa to search for chromite for the Tata Iron & Steel Company. A good number of other requests—involving geophysical investigations relating to groundwater, harbour construction, dam projects—had to be declined because of the limited facilites so far available at this new Institute. In view of the CSIR's general emphasis on applied and economic work, and especially in view of the serious deficits in India's mineral production as explained earlier, it is intended to considerably strengthen the exploration group of NGRI. While the Geological Survey of India will continue to carry the brunt of the burden of geophysical investigations for minerals, the contribution of NGRI's mite can be a welcome supplement.

World statistics in geophysics

The Society of Exploration Geophysicists of the United States of America publishes every year a detailed article on the geophysical activity in the previous year. The December 1964 issue of Geophysics gives the statistics of the geophysical activity in the year 1963. This report gives the statistics of countries other than the USSR and China though it reports that extensive activity is known to exist in USSR.

In mining geophysics (excluding USSR and China) a sum of over $12·5 million was spent in 1963 in ground and airborne surveys, and research—the proportion being 47·9, 39·4 and 12·7 per cent respectively. Tables 5 to 7 taken from the report indicate the expenditure incurred on the various techniques of ground geophysical surveys, air-borne methods and research. They also show areawise expenditure incurred on mining geophysical activity during 1963. It is obvious from Tables 5 to 7 that the mining geophysical activity in Asia as a whole accounts for only 1·1 per cent

Table 5—Mining geophysical activity Ground methods

	Expenditure in US dollars				
	Industry		Government	Total	Percentage
	Company	Contract			
By method					
Magnetic	402,700	215,300	176,900	794,900	13.2
Resistivity	55,300	745,400	210,900	1,011,600	16.8
Induced polarization	274,100	1,071,500	36,500	1,382,100	23.0
Earth current	3,000	25,100	0	28,100	0.5
Self-potential	32,300	46,600	11,800	90,700	1.5
Electromagnetic	356,600	92,400	81,800	530,800	8.8
Gravity	205,100	201,100	473,100	879,300	14.6
Seismic	29,100	136,800	157,800	323,700	5.4
Radio active	5,100	3,100	23,600	31,800	0.5
Geochemical	368,400	124,900	311,100	804,400	13.4
Drill hole logging	32,100	25,200	65,800	123,100	2.0
Miscellaneous	5,000	0	12,500	17,500	0.3
Total	1,768,800	2,687,400	1,561,800	6,018,000	100.0
By area					
Africa	320,900	503,500	155,000	979,400	16.3
Asia	50,300	40,100	24,700	115,100	1.9
Australia	152,000	430,100	277,900	860,000	14.3
Canada	695,900	460,100	298,300	1,454,300	24.2
Europe	169,500	557,500	511,200	1,238,200	20.6
Latin America	7,100	176,300	156,200	339,600	5.6
United States	373,100	519,800	138,500	1,031,400	17.1
Total	1,768,800	2,687,400	1,561,800	6,018,000	100.0
Percentage of total	29.4	44.7	25.9	100.0	

Table 6—Mining geophysical activity—Research

	Expenditure in US dollars			Total	Percentage
	Industry	University	Government		
By method					
Magnetic	102,100	29,800	164,200	296,100	18.6
Resistivity	211,000	11,100	1,100	223,200	14.0
Induced polarization	122,300	11,700	7,100	141,100	8.9
Earth current	1,100	45,400	0	46,500	2.9
Self-potential	2,700	0	0	2,700	0.2
Electromagnetic	94,400	4,100	17,300	115,800	7.3
Gravity	26,500	18,800	11,200	56,500	3.5
Seismic	13,000	67,700	261,400	342,100	21.5
Radioactive	0	11,500	8,800	20,300	1.3
Geochemical	111,100	16,300	106,300	233,700	14.7
Drill hole logging	2,800	1,900	5,200	9,900	0.6
Miscellaneous	78,200	0	25,400	103,600	6.5
Total	765,200	218,300	608,000	1,591,500	100.0
By area					
Africa	0	30,000	3,800	33,800	2.1
Asia	7,200	10,400	0	17,600	1.1
Australia	800	19,100	5,400	25,300	1.6
Canada	121,800	2,000	173,000	296,800	18.6
Europe	129,700	82,100	47,400	259,200	16.3
Latin America	800	0	0	800	0.1
United States	504,900	74,700	378,400	958,000	60.2
Total	765,200	218,300	608,000	1,591,500	100.0
Percentage of total	48.1	13.7	38.2	100.0	

Table 7—Mining geophysical activity—Airborne methods

	Expenditure in US dollars			Total	Percentage
	Industry		Government		
	Company	Contract			
By method					
Magnetic	57,500	2,951,000	276,100	3,284,600	66·4
Electromagnetic	105,000	0	0	105,000	2.1
Combined magnetic & electromagnetic	326,000	710,000	331,000	1,367,000	27.7
Infrared	0	3,600	4,200	7,800	0.2
Radioactive	0	0	178,500	178,500	3.6
Total	488,500	3,664,600	789,800	4,942,900	100.0
By area					
Africa	0	717,600	159,000	876,600	17.7
Asia	0	54,000	0	54,000	1.1
Australia	0	410,700	22,200	432,900	8.8
Canada	444,000	1,782,200	0	2,226,200	45.0
Europe	32,000	103,900	331,000	466,900	9.5
Latin America	0	270,000	56,500	326,500	6.6
United States	12,500	326,200	221,100	559,800	11.3
Total	488,500	3,664,600	789,800	4,942,900	100.0
Percentage of total	9.9	74.1	16.0	100.0	

of the total activity in the world other than USSR and China. Among the ground methods of geophysical exploration for minerals, Canada leads with a percentage of 24·2 followed by Europe 20·6, USA 17·1, Africa 16·3, Australia 14·3, Latin America 5·6 and Asia 1·9.

In geophysical research as applied to mineral exploration, the United States accounts for 60·2 per cent of the total expenditure incurred on research in 1963, followed by Canada 18·6, Europe 16·3, Africa 2·1, Australia 1·6, Asia 1·1 and Latin America 0·1 per cent. Mining Geophysical activities in the USA, Canada, Europe, Australia, Africa and in the USSR have well established their importance in exploration of mineral resources. Their importance is well established by their continued use and expenditure of large amount of money on research in those countries. It is essential that their importance is properly appreciated within the country and these techniques are used on a much larger scale to establish the mineral resources in India.

Applied research in mineral exploration

While geophysics, geochemistry and other specialized techniques have undoubtedly proved of great value in mineral exploration, there is yet great scope for applied research towards design and manufacture of instruments, data processing, improved methods of interpretation, development of new and/or modified field prospecting techniques, and so on. The preceding section has indicated how substantially USA, USSR, Canada and other advanced countries spend on applied research of this kind. The present emergency has clearly shown how very dangerous it is to depend and rely upon the import of technical know-how from abroad. The desirability of our taking up such developmental work and its urgency cannot thus be overemphasized.

Geophysical instrumentation. Some 15 organizations in the country are at present using geophysical instruments for exploration, research, teaching, earth studies etc. Almost all the instruments have been imported from abroad. The total cost, in terms of foreign exchange spent, is estimated at Rs 138.5 lakhs. Out of this Rs 66 lakhs approximately have been spent during the last five years. The proposed imports during the Fourth Five-Year Plan will involve an estimated expenditure of Rs 159 lakhs in foreign exchange, an amount more than the cost of all the imports made up-to-date.

With the raw material, components and know-how available in the country now it appears to be possible to save nearly 60 per cent of the estimated foreign exchange expenditure. if the balance is spent in purchasing mainly components and raw material, rather than complete instruments. Thus many of the magnetic, electrical and seismic instruments could be manufactured in the country either wholly out of indigenous components and material or by using some imported items.

All the know-how available in the country is not with any single organization. Collaborative work by more than one organization will be necessary for the manufacture of prototype instruments which may eventually be given out to production organizations in the country. The National Geophysical Research Institute, Hyderabad, and Central Scientific Instruments Organization, Chandigarh can have much to do in this regard. Such a venture is now all the more necessary in view of the difficult foreign exchange position.

A more detailed consideration of all these aspects have been included in a paper entitled 'Geophysical Instrumentation', submitted to the Working Group 1.

Development of methods and techniques. As the shallower and bigger deposits dwindle, development of effective methods for locating deep ore bodies become more and more pressing. It has been estimated, for example, that if the entire present population of the world could use mineral and ore products to the same extent as in USA, all known deposits of such materials as copper, lead, zinc and petroleum would be exhausted within five years. Several approaches seem possible. One possibility is to develop some suitable stacking techniques, as in seismic method for petroleum, that will enhance the weak signals and suppress noise in the electrical and electromagnetic methods. Another is the modification of the seismic method itself for application to mining problems. The ore bodies have very often seismic velocities and densities which are both appreciably higher than the neighbouring rocks. To be able to use these differences would mean an almost unlimited increase in the depth range of the mining geophysics. A third possibility is the method of energizing the ore body itself when pierced by a bore hole.

The third alternative of the preceding para also implies the development of bore hole equipment—magnetometer, gravimeter, electrical and electromagnetic instruments. In general, it is necessary to develop what is known as Underground Geophysical Surveying which utilizes observations in bore holes, shafts, galleries and in underground mining levels. Special methods of reduction of data and their interpretation are necessary.

There is a good deal to do towards improvement of interpretation of any geophysical techniques. Almost all methods of interpretation of any geophysical data assumes that the measurements were made on a flat ground surface. This assumption is almost never satisfied, since mining prospects invariably have uneven topography. It is thus necessary to develop interpretation procedures that can directly utilize data collected at varying elevations. Interpretation of vertical (bore hole) profiles is another aspect that requires to be developed almost from the beginning. Model and theoretical studies for quantitative interpretation of electromagnetic data require a good deal of continuing attention. A great deal remains to be done by way of data processing techniques based on magnetic tape or other reproducible form of recording—as is evident from the spectacular advancements made in the field of petroleum geophysics.

Another fertile field is the development of facilities and techniques for mineral exploration in offshore areas. Recently, an expert Working Group, under the auspices of ECAFE, has recommended extensive offshore geophysical surveys along the Asian coastline.

Ore genesis in exploration. From the study of various mineralogical, stratigraphic, and structural associations of ore minerals to the immediately adjoining rocks, it is possible to trace and look for new ore bodies in a given area of limited extent. These guides depend upon the type of mineralization, nature of host rock, temperature-pressure conditions, and such structural features as fractures, faults, folds, shear zones etc.

To a limited extent, we are aware of the chemical and structural relationships of metalliferous deposits to the immediately adjacent rocks. But our knowledge about the structural relationships and chemical

processes taking place at the very roots of those deposits deep within the crust and the mantle beneath is very poor. And it is these unknown forces and structures that are presumably the source of mineralizing agents.

From the study of petrology of various rock types and associated ore minerals and their relation to the tectonic and metamorphic evolution of rocks of an area, distinct metallogenic provinces can be outlined. However, techniques have to be developed to learn to recognize and delineate even under thick cover, the signs that point to a metallogenic province, and within that province to the loci of mineral concentration. This calls for an integrated research programme in the disciplines of geology, geophysics, and geochemistry. And it is through such studies that we can improve our knowledge of the geophysical, geochemical and geological manifestations of ore and mineral deposits.

By knowing these interrelationships of different factors we may be able to evolve an overall picture of intricate history of evolution and mineralization of the area. This will help to direct our efforts in prospecting and exploration of ores within a small area, and may also lead to development of techniques to be utilized in other regions.

APPENDIX

Geophysical surveys for minerals and ores by area, mineral and method (Locations plotted in Fig. 2 by the serial numbers in this Appendix)

(E, Electrical & electromagnetic; M, Magnetic, G, Gravity.)

Sl No.	Area	State	Mineral	Method of survey
(1)	(2)	(3)	(4)	(5)
1.	Nellore District	Andhra Pradesh	Copper	EM
2.	Singhbhum Copper Belt	Bihar	Copper	EM
3.	do	do	Copper	EM
4.	do	do	Copper	EM
5.	Kurnool District	Andhra Pradesh	Copper	EM
6.	Singhhum Copper Belt	Bihar	Copper	EM
7.	Kurnool District	Andhra Pradesh	Copper	EM
8.	Singhbhum Copper Belt	Bihar	Copper	EM
9.	Jabalpur District	Madhya Pradesh	Copper	EM
10.		Gujarat	Copper	EM
11.	Karnal District	Punjab	Copper	EM
12.	Khetri Copper Belt	Rajasthan	Copper	EM
13.	Information not available			
14.	Jabalpur District	Madhya Pradesh	Copper	EM
15.	Kurnool District	Andhra Pradesh	Copper	EM
16.	Khammam District	do	Copper	EM
17.	Alwar District	Rajasthan	Copper	EM
18.	Khetri Copper Belt	do	Copper	EM
19.	Anantapur District	Andhra Pradesh	Copper	EM
20.	Guntur District	do	Copper	EM
21.	Khetri Copper Belt	Rajasthan	Copper	EM
22.	do	do	Copper	EM
23.	do	do	Copper	EM
24.	Khammam District	Andhra Pradesh	Copper	EM
25.	Singhbhum Copper Belt	Bihar	Copper	EM
26.	Khetri Copper Belt	Rajasthan	Copper	EM

(*Contd*).

(1)	(2)	(3)	(4)	(5)
27.	Karimnagar District	Andhra Pradesh	Copper	EM
28.	Kasi Hills	Assam	Copper	EM
29.	Pachikhani Belt	Sikkim state	Copper	EM
30.	Singhbhum Copper Belt	Bihar		
31.	Khetri Copper Belt	Rajasthan	Copper	EM
32.	Jaipur District	do	Copper	EM
33.	Guntur District	Andhra Pradesh	Copper	EM
34.	Jaipur District	Rajasthan	Copper	EM
35.	Almora District	Uttar Pradesh	Copper	EM
36.	Singhbhum Copper Belt	Bihar	Copper & lead	EM
37.	do	do	do	EM
38.	Bhilwara District	Rajasthan	Copper	EM
39.	Jaipur District	do	Copper & lead	EM
40.	Almora District	Uttar Pradesh	do	EM
41.	Udaipur District	Rajasthan	do	EM
42.	Jaipur District	do	do	EM
43.	Singhbhum Copper Belt	Bihar	do	EM
44.	Kurnool District	Andhra Pradesh	do	EM
45.	Hazaribagh District	Bihar	do	EM
46.	Kulu Valley	Punjab	Copper	EM
47.	Varikunta, Cuddapah District	Andhra Pradesh	Lead & copper	EM
48.	Agnigundala, Guntur District	do	Copper, lead & zinc	EM
49.	do	do	do	EM
50.	Kurnool District	do	do	EM
51.	Jammu Province	Jammu & Kashmir	do	EM
52.	Jaipur District	Rajasthan	do	EM
53.	North Arcot District	Madras	Lead & barites	E
54.	Durg District	Madhya Pradesh	Lead, zinc & flourite	E
55.	Hospet District	Mysore	Galena	EMG
56.	Cuddapah District	Andhra Pradesh	Lead & zinc	EM
57.	Karwar District	Mysore	Pyrite	EM
58.	Sawai, Madhopur District	Rajasthan	Lead & zinc	EM
59.	Sawai, Madhopur District	do	do	EM
60.	Gondite Manganese Belt	Madhya Pradesh	Manganese	EM
61.	do	do	do	M
62.	do	do	do	M
63.	do	do	do	M
64.	do	do	do	M
65.	do	do	do	MG
66.	do	do	do	MG
67.	do	do	do	EM
68.	Gondite Manganese Belt	Madhya Pradesh	Manganese	EM
69.	Srikakulam District	Andhra Pradesh	do	EM
70.	Gondite Manganese Belt	Madhya Pradesh	do	EM
71.	do	do	do	MG
72.	Chaibasa	Bihar	Chromium	MG
73.		Mysore	Chromite	MG
74.	Dhurkanal District	Orissa	do	MG
75.	Cuttack District	do	do	MG
76.	Nagpur District	Maharashtra	Chromium	EM
77.	Midurapore District	West Bengal	Tungsten	EM
78.	Durga, Jodhpur District	Rajasthan	do	EM
79.	Agargaon, Nagpur District	Maharashtra	Wolframite	EM
80.	Hazaribagh District	Bihar	Vermienlite	EM
81.	Amba Dongar, Baroda District	Gujarat	Flourite	EM
82.	Jammu Province	Jammu & Kashmir	Pyrrhotite	M
83.	Udaipur District	Rajasthan	Pyrrhotite	EM
84.	North Arcot District	Madras	do	EM
85.	Chitaldrug Pyrite Belt	Mysore	Sulphide ores	EM
86.	do	do	do	EM

Contd

Appendix—*Contd*

(1)	(2)	(3)	(4)	(5)
87.	Chitaldrug Pyrite Belt	Mysore	Sulphide ores	EM
88.	do	do	do	EM
89	do	do	do	E
90.	do	do	do	EM
91.	Khammam District	Andhra Pradesh	do	EM
92.	Hazaribagh District	Bihar	do	EM
93.	Kanyakumari District	Madras	Nickelliferrous Pyrrhotite	EM
94.	Khammam District	Andhra Pradesh	Graphite	E
95.	Dhukarnal District	Orissa	do	E
96.	Venganoor, Trivandrum District	Kerala	do	E
97.	Bolangir District	Orissa	do	
98.	Sambalpur District	do	do	E
99.	Puliarkonam, Trivandrum District	Kerala	do	E
100.	Kalijhar, West Sikkim	Sikkim State	do	E
101.	Sambalpur District	Orissa	do	E
102.	Panalur, Quilon District	Kerala	Graphite & pyrrhotite	E
103.	Panna Diamond Belt	Madhya Pradesh	Diamond	M
104.	do	do	do	M
105.	do	do	do	M
106.	Vajra Karur, Anantapur District	Andhra Pradesh	do	EMG
107.	do	Bihar	China clay	EM
108.	Sundergarh area	Orissa	Limestone	EM

Oceanography as Applied to Industry

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Oceanography is the study of the oceans, including the living and non-living matter they contain. Its objective is to increase our knowledge of the properties and behaviour of ocean waters, the movement of these waters, the character and composition of the various sediments and rocks constituting the ocean bottom, the physical and chemical interaction between the sediment-water interface on the one hand and air-sea interface on the other. The science of animal and plant life that inhabit the seas is itself a vast field for biological work. Oceanography is thus a composite science bringing together the fundamental concepts and theories from all basic sciences with a view to a complete understanding of what is going on in the various oceans which constitute nearly 71 per cent of the total earth's surface.

Oceanography is a comparatively young science and much development in this field has taken place in the most advanced countries during the past two decades. During this short period of time, the science has made great strides and is fast becoming a vast field of scientific endeavour with its own techniques and methodology.

Oceanographic research resources oriented

While it is, no doubt, true that the basic objectives of the science of oceanography is to enlarge our knowledge of the oceans, it has its applied side also. In fact modern oceanographic research is becoming Resources-oriented which means to say, that the research has, in recent years, been directed more and more towards exploitation of oceanic resources—both living and non-living. The living resources include the fishery resources both in the inshore and offshore areas and also the vast amounts of plants and other animals occurring in the various oceanic areas. Apart from utilizing these for food, there are vast possibilities of using them as industrial raw material. Among the non-living resources are included the minerals and salt present in solution in seawater as well as in the bottom deposits. The undersea petroleum deposits are also included in the category. These stores are virtually inexhaustible, but the exploitation of only a few of these has been undertaken in recent years. The exploitation of others have to await further developments in mining technology, although a good deal of research is going on on the distribution of these in various areas, and the possibilities of their exploitation.

The possibilities of orienting oceanographic research towards industrial development are indicated under a few broad categories mentioned below. In this we have given a much broader interpretation to the term 'industrial development' by including the fishing industry and also facilities such as oceanic shipping for the efficient transport of raw materials and industrial products, as this is important from the point of view of trade promotion.

The main categories are : (i) oceanography and fishing industry ; (ii) oceanography and marine minerals industry ; and (iii) application of oceanograhic knowledge to quick and efficient oceanic transportation.

Oceanography and fishing industry

The country's immediate need is food, and one of the ways of meeting these requirements is to increase our seafood resources. Under seafood we include fish, shellfish and other fishery products.

Increasing demand for seafood cannot be satisfied simply by expanding the fisheries for the most familiar and currently exploited species. We have to explore unfamiliar resources, develop methods of exploiting and using them and create public awareness in these. The exploration of the new unfamiliar resources forms an essential part of the oceanographic research and this also includes studies of behaviour pattern of the offshore fishes in their natural environment, so that the knowledge could be applied to designing the most efficient gear and techniques for their exploitation. These exploratory researches go a long way in assisting the growth and development of fishing industry in the country and help in the exploitation of the fishery resources in the most economical way.

Fishermen spend a good deal of time and effort in searching for their quarry. One of the most effective means of reducing the present fishing costs, both for the underutilized and fully utilized stocks would be to improve methods of predicting the times and places where fish will concentrate. To be able to do this it is absolutely necessary for us to enlarge our understanding of the oceanic environment. Oceanographic research will be able to contribute much in this direction by providing the fishing industry with detailed charts of all important oceanic parameters in different geographical regions in the seas around India and also during the different seasons of the year. The charts will also show the possible fish concentrations associated with these different oceanographic conditions and also provide a forecasting service for fishing conditions. Such composite charts are issued in countries like Japan for the benefit of the fishermen and the fishing industry. The industry will benefit a great deal from these charts and the fishermen will be able to plan their operations, modify their gear to suit different conditions, so that they may not only get good return for their investments, but also ensure sustained yields in the future years.

Apart from the utility as food, the fishing industry will also be able to provide the essential raw materials for other industries as well. While being able to utilize all edible fish for food, the fishing industry can also find suitable uses for what are known as 'Trash fish'. The fishery technological development has progressed so much in these years that a variety of industrial products are being manufactured utilizing all these 'trash fish'. The status of these industries is too well known to need emphasis here. Oceanography can play a very important role in ensuring a continuous supply of the basic raw material for these industries.

Oceanographic research and marine minerals industry

Oceanographic research is able to contribute to a great extent in the industrial development relating to the exploitation and utilization of marine minerals. It should, however, be pointed out that at present there are only a few industries that are able to utilize the vast mineral wealth of the sea. This has been so partially because in many countries the land mineral resources have been in great abundance and they have not reached anywhere near the state of depletion. However, in certain cases it should be possible to obtain minerals from the sea in a higher state of purity as compared with land sources and the costs of further treatment could be reduced. It is one of the aims of oceanographic research to do prospecting for such types of mineral resources.

The marine minerals of the sea could be broadly classified under the following heads :

(1) Those present in solution as sea salts

(2) Those present in the nearshore sediments and sands and are almost a continuation of the beach deposits

(3) Those present in rocks or consolidated sediments on the continental sediments

(4) Those present in the great depths of the ocean as concretions or nodules

As regards (1), the most important ingredient is sodium chloride (common salt) and the salt industry is one of the oldest industries in the country, as well as elsewhere in the world The salt and the byproducts of salt industry like potassium chloride, magnesium sulphate etc. are being utilized to a considerable extent. Among the many subsidiary industries arising out of the main salt industry, mention is made of the manufacture of chemicals like potassium chloride, magnesium salts such as magnesium chloride, magnesium oxychloride, magnesium oxides and hydroxides. Another important industrial product is bromine from the bitterns. Although caesium and rubidium are two important chemicals which could be obtained from the seawater, in view of the fact that their industrial significance have not yet been fully understood not much effort is being directed towards their extraction. As regards other chemicals from seawater, these are present in such low concentrations, that special technologies have to be evolved for the concentration of these.

Minerals obtainable from nearshore sediments and continental shelves

The minerals under this category are mostly placer deposits about which we have practically no knowledge along our coasts. The one possibility is to explore for titanium sands in the nearshore deposits off our southwest coast. While the occurrence of monazite sands containing thorium and rare earths are known to occur in the heavy mineral fractions of the beach sands along the south Kerala coast, it would be necessary that the exploitation of these should be simultaneously accompanied by the exploration for the occurrence of these in the undersea deposits of the nearshore areas. It is also a well-known fact that there is a considerable amount of erosion of these beaches (which may lead to the loss of these valuable minerals to sea) and efforts are being made to evolve methods for checking erosion. There are two possible ways in which oceanographic research can help towards

utilization and conservation of these valuable mineral resources. One is by studying the oceanographic conditions in the nearshore areas such as waves, currents, sediment movements etc. which are responsible for this erosion and based on such studies suggest suitable means for stabilizing these beaches so that we may be able to conserve these valuable mineral resources. Secondly, the offshore explorations should be carried out to determine the sea ward extent of these valuable deposits and work out suitable methods of exploiting these. This is one of the most important projects which could be taken up and which would probably be able to yield quick returns. As we do not have any information regarding these aspects, it would be premature to attempt to make any estimate—even a rough one—of these nearshore deposits.

One industry that is making a really major investment in ocean research is the petroleum industy. Exploration or prospecting for petroleum deposits involve a considerable degree of oceanographic knowledge and information and any expenditure spent in this direction to acquire the necessary data, will certainly be worthwhile. The industry has to depend on oceanographic researches to obtain knowledge concerning the effect of wave motion, storms and related phenomena on platforms that must be built in greater and greater depths as the search for oil widens out into the seas. While a beginning is yet to be made in this country, in regard to other areas of the world it is found that the combined efforts of petroleum companies in such places as the Gulf of Mexico, the Northsea, the Persian Gulf, and many other places account for more of the money for ocean research than do all other industries exploiting the seas combined. Among the mineral resources of the continental shleves, one of the most important are the phosphate rocks (phosphorites) which are present mostly as nodules in many places on the outer continental shelves and offshore banks. The only estimates of the phosphorite deposits in the sea bed we have, are the American deposits off the southern California coast, where 50 to 60 million tons of phosphatic minerals are said to be present. Most of these deposits are of the apatite group (like fluorapatite) and are very much similar to the land deposits of the phosphate rocks. Phosphates are, as is well known, an important component of the fertilizer industry and one of the easiest ways of obtaining the phosphates from these rocks is by simple acid treatment. Hence phosphate rocks have a great importance as a raw material not only for phosphatic fertilizers but also for elemental phosphorus and phosphorus compounds.

The total world reserves of phosphatic rocks is estimated to be 46,800 million tons in terms of P_2O_5, of which nearly 45 per cent is from Morocco and 30 per cent from USA. The world production of phosphorites is about 46.0 million tons (1962–63 figure) of which 19.4 million tons are produced by USA, 8.57 by USSR and 8.03 by Morocco. Thus the major part of the production of this valuable mineral is concentrated in these three countries and practically the entire quantity is from land deposits only. USA is the only country which has started exploitation of this mineral from the mineral source. India has been importing phosphate rocks to the value of about Rs 6.50 lakhs during the period 1963–65. At present the only alternative that has been considered for our phosphate needs is the basic slag from the iron and steel industry. It would no doubt be worthwhile to explore the possible occurrence of deposits of phosphate rock on the continental shelves off our coasts, the main consideration being that some of these areas have oceanographic conditions almost similar to what has been off the coast of southern California. According to an eminent authority,

"other potential phosphate deposits off Australia or India, for example, appear promising. As a rough estimate, a new industry with a gross value of $ 10 to $ 20 millions could be developed within the next decade. A world-wide search for undersea phosphate, and basic research on the mechanisms and conditions of its formation*, would cost several million dollars a year, but it could pay off handsomely!

Another potential mineral source is the deep ocean deposits particularly the manganese nodules, containing manganese, iron, cobalt and copper, distributed in several areas on the ocean floor of Pacific and Indian Oceans. These nodules contain as much as 25 to 30 per cent of manganese in a fairly high state of purity. However, the present knowledge of the distribution and composition of these manganese nodules is inadequate to justify a heavy industrial investment. The indications, however, are that with the fast growing oceanographic knowledge and with the rapid rate of developments in mining technology, these reserves could become economically mineable within a decade or two. Oceanographic research would, however contribute much in this direction by providing the necessary basic information concerning the distribution of these nodules in the different areas and also the conditions and mode of their formation.

Application of oceanographic knowledge to ship-routing

With the growth of industrialization and the expansion of world trade the entire world storehouse of raw materials is drawn upon to meet the needs of new machines and as a consequence shipborne commerce is fast increasing. A reduction in the cost of ocean shipping would serve the interests of both the advanced and less developed countries. Lower shipping costs would help considerably countries like India, by promoting exports and reducing import costs of items like heavy machinery. Oceanographic research is making a significant contribution to reduction in ocean fuel costs. To cite a few examples, better statistics on sea surface waves would help us to improve the design and lower the costs of new ships. Through improved forecasts of waves, wind and currents, ships could be better routed along minimum time paths . both fuel consumption and time at sea would be considerably reduced. Improved routing would also lower storm losses. Stranding and collision losses could be lowered through improvements in navigation, based on more detailed knowledge of sea bottom topography. Greater knowledge of nearshore wave and current conditions and sea floor characteristics is needed for improvement of existing harbours and construction of new ones.

The above observations would indicate that although oceanography is a combination of several basic sciences, there are important aspects of applied value in this field of research. Some of them having a very important part to play in the discovery of new raw materials from the sea both living and non-living. The food resources from the living material and the mineral resources from the sea bottom offer great possibilities at a time when both these are badly needed for a world where population and industrial activity are both fast expanding and the material resources of the land are becoming increasingly limited.

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Development of the Asbestos Mining Industry of Andhra Pradesh

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From the standpoint of industrial use, the most important variety of asbestos is chrysotile ; it makes up about 92 per cent of the world production of asbestos. World demand for asbestos far exceeds supply. It is a strategic mineral vital to the needs of defence industries.

High grade chrysotile asbestos suitable for weaving is available in commerical quantities, as far as existing knowledge goes, only in the Cuddapah district of Andhra Pradesh. Indications of its occurrence are also available in the Kurnool district and in the States of Bihar, Mysore and Rajasthan. However, Cuddapah district alone has been the producer of chrysotile in commercial quantities to this day. The pre-war pit's mouth value of Cuddapah asbestos ranged between Rs 300 and Rs 400 per ton compared to the Rs 40 per ton of amphibole asbestos produced in Bihar, Mysore and Rajasthan.

Even with regard to chrysotile asbestos, the specifications for use in electrical insulation are very rigid calling for a maximum of 1.75 per cent of total iron and not more than 0.75 per cent of magnetic iron. This is in very short supply in the American continent. Canada's chrysotile asbestos does not satisfy this specification. The USA's own sources in Arizona are too meagre to meet its demands. The only other sources which meet these specifications are Southern Rhodesia, the USSR, and Cuddapah district of India. Almost the entire production of this quality outside the USA, USSR and India is controlled by a single firm, viz. Turner and Newall Ltd of Manchester, England. They are the principals of Messrs Asbestos Cement Ltd of India.

Asbestos mining industry of Cuddapah district

In spite of its commanding position as the producer of the most valuable variety of chrysotile asbestos, Cuddapah district has been suffering a steady decline in production. From 293 tons in 1959 it has come down to 43 tons in 1963, the latest year for which statistics are available. On the other hand, production of the cheaper amphibole variety of asbestos has been increasing in Bihar, Madhya Pradesh and Rajasthan. Andhra Pradesh does not produce this variety.

The reasons for this state of affairs are many. The most important are: (a) the nonavailability of cheap and adequate electric power in the earlier

years, and (b) the inability or unwillingness of the existing lessees, even when such power has become available, although neither cheaply nor in adequate measure, to invest the capital necessary to reorganize their mines based on electrification to compensate for the increasing depths of mining, increasing wages and more stringent statutory obligations regarding safety and welfare.

Foreign markets

The increasing competition from the USSR in the international asbestos market resulting from its need to earn foreign exchange, especially dollars, to secure capital goods from abroad directly affected Turner and Newall's markets for the superior grades in the USA, the world's largest consumer, whilst its natural outlet for the inferior grades in India was threatened by the increasing production of the cheaper amphibole variety inside India. In 1952–53, as a part of its plan to tighten its strangle-hold on the asbestos consuming industries of India, Turner and Newall arranged for Asbestos Cement Co. Ltd to bring out here a mining 'expert' ostensibly to explore the scope for increasing production of crysotile in India, having earlier made out, to the bureaucrats of the Mininstry of Commerce & Industy who alone mentioned that the amphibole asbestos being produced in India was no suited to the asbestos cement industry and that chrysotile asbestos resources must be explored in India. This meant in practic that the Indian amphibole asbestos industry would be forced to contract and that the Asbestos Cement Co. Ltd would continue to draw on its overseas sources through Turner and Newall whilst we are kept busy engaged in the search for chrysotile asbestos sources all over India.

Meanwhile, the acute foreign exchange crisis in the country resulted in the appointment, by the Ministry of Commerce & Industry, Govt of India, of the Asbestos Committee in January, 1956. This committee consisted of two technical 'experts' of Messrs Turner and Newall, a mine manager from Southern Rhodesia and a geo'ogist al o from the same country both juveniles. The only Indian technician in the Committee was an officer of the Geological Survey of India, Shri S. Krishnaswamy, a geologist. No Indian mining engineer was associated with a committee that was to decide the fate of the Indian asbestos industry.

The Committee visited all the known occurrences of chrysotile asbestos in the country, namely, Bihar, Mysore, Rajasthan and Cuddapah district of Andhra Pradesh. Had this committee been objective in its approach, even assuming that they were competent enough for the task entrusted to them which was not the case, they would have been able to understand the reasons for the long and continuous history of production in Cuddapah district, the lack of interest on the part of any entrepreneur in the chrysotile occurrences, in the other States in all of which the cheaper amphibole asbestos production was increasing, and the reasons for the decline of the industry in the Cuddapah district. However, they chose to draw conclusions ostensibly on the basis of theoretical geology but actually to subserve the S. Rhodesian interests of Turner, Newall & Co. and made the following recommendation in regard to the Cuddapah deposits:

> "It is considered that this type of chrysotile deposit where the formation of fibre occurs in dolomitic limestone usually does not provide sizeable reserve of ore for large scale mining operations. Even in such area, however, it may be possible to locate limited reserves of workable ore which could be mined by small scale operation !"

Of course, on an elementary consideration of the first principles of mining alone, the correct recommendation for exploiting deposits in this geological setting is just the opposite of the above necessitating more detailed exploration and large scale mining to make of it into an economically successful proposition. But then, a mine manager is not necessarily a mining expert just as an estate manager is not necessarily an agricultural expert !

Thus, in spite of a note of dissent submitted by Shri S. Krishnaswamy, the Committee gave Cuddapah the last position in the order of priority for detailed exploration among all the known occurrences of chrysotile asbestos occurrences of India. The report of the Committee was submitted to the Government of India in March 1961 ; and, to make sure their recommendations are not questioned or criticised by anyone in the know of things, Messrs Asbestos Cement Co. Ltd prevailed upon the Govt. of India to treat this report as a confidential document.

As should be clear now to everyone, none of the deposits of Bihar, Mysore or Rajasthan have produced any chrysotile worth the name. None of them have, in fact, come up anywhere near to the expectations held out by this committee despite all the efforts specially directed towards their exploration by the Govt. of India. On the other hand, the indifference displayed by the government towards the exploration and development of the Cuddapah deposits consequent to the recommendations of the so-called 'experts' of Turner and Newall who had a deep vested interest in preventing the development of the only premium grade chrysotile asbestos producing region in India in Cuddapah, has affected this strategic sector of our mining industry.

Approach to a remedy

As a result of the keen personal interest taken in this important matter by the Hon'ble Dr M. Chenna Ready who recently visited the area and inspected the underground workings of the APMC's mine at Brahmanapalli near Pulivendla and the watchful brief over the development of this region always held by the Hon'ble Dr N. Sanjeeva Reddy, it has been possible for me, as a director of the Andhra Pradesh Mining Corporation Ltd to examine the position *de novo* and to make a detailed, on-the-spot study of the asbestos regions of Cuddapah and Kurnool districts.

As a preliminary to the visit, I made a detailed examination of the technical data from the Corporation's own prospect and from the neighbouring mines, collected under my instructions by the geologist of the Corporation. Analysis of this data revealed that on the basis of 6 ft high tunnels driven through the asbestos-bearing zone, the percentage recovery of fibre is on an average 0.6, and the value per ton fibre recovered is Rs 2000. These are conservative estimates, much below the values obtaining today in the Corporation's own prospect and the neighbouring working mines. However, even on the basis of these conservative estimates of value-recovery, it is possible to make operations to break even. Any improvement in values and the recovery or the creation of a market for the byproducts like serpentine and dolomite will only make the position much more attractive than what it apparently appears to be.

Plans for the present and the immediate future

The appended estimate is for immediate work the object of which is to solve the technical problems involved in planning for large scale mining

operations encompassing the entire asbestos belt from Lingala to Chinnakudala. In the first stage of operations, with a yield around 0.6 per cent of rock broken in 6 ft high tunnels and a value of Rs 2000 per ton of yield, it works out to Rs 12 per ton of rock mined. This means, to break even in the drivage of 6 ft tunnels, the cost of production has to be below Rs 12 per ton. If, however, a method of mining is adopted in which this development stage is dovetailed into the stage of stoping by the adoption of some system of longwall where the height of working need not be more than 2 ft 6 in., the yield would automatically increase to 1.4 per cent that is Rs 28 per ton providing for adequate scope for profitably mining.

The exact method of longwall work, whether it should be by advance or retreat, the length of faces, the rates of advance, the system of support, ventilation and haulage at the face and other details will have to be worked out on the basis of actual experience obtained during the next few months. The present estimates provide for all costs, both direct and indirect, and would not involve us in any additional capital expenditure beyond what has been now provided for. In about a year we would be able to secure enough technical data to be in a position to finalize plans for a major project consisting of optimum-sized properties including the entire asbestos belt even after excluding those areas which are held today by private parties and which, in no case, extend much beyond the outcrop.

Such a major project, however, demands advance preparation in three respects : (i) drilling to secure essential data in regard to the nature and continuation of values to depths, in the first instance, to at least 1000 ft (vertical); (ii) detailed geophysical and geological study of the asbestos belt on modern lines which has not been done so far; and (iii) an assured supply of electrical power, at least 500 kW. to begin with.

Investigations on Nickel Bearing Laterites in India

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Nickel is one of the metals which have widest varieties of uses. Only in few applications nickel is used in pure form. But as an alloying element for imparting special properties it is an essential constituent of several thousands of alloys. These alloys have applications in various fields of industries where there are rigid demand on special properties, such as mechanical strength, toughness, wear resistance, resistance to corrosion and high temperature, unusal magnetic, thermal and elastic properties. Nickel being an indispensable component of such a variety of alloys, is a strategic material and its availability is one of the most important items in the planning of any country.

In India, indigenous sources of nickel known so far are hardly of any commercial significance. Neither of the usual natural sources of nickel—sulphides and silicates—or oxides have yet been found in workable deposits. In India nickle has been found to be associated with chalcopyrite in Singhbhum district, Bihar. But it is not recovered in the copper smelting plant in Singhbhum. Most of its remains in the final copper metal product. Moreover, total production of about 8000 tons of copper in Singhbhum will yield only a few hundred tons of nickel. But if the copper production is increased considerably and electrolytic refining of copper is carried out, considerable amount of nickel may be recovered as a by product. Even this will not meet India's demand for nickel which is increasing rapidly. Not much association of nickel has been found in sulphide minerals in other areas of India. Thus prospect of a large yield of nickel from sulphides cannot be considered high.

The importance of study of nickel in silicate or oxide form thus becomes more pronounced. Actually nickel ore of this type produced from New Caledonia was considered the most important source for nickel at the beginning of the present century, till the phenomenal development of sulphide ores in Sudbury, Canada. Discovery of huge quantities of secondary nickel mineralization as oxide and silicates in Cuba and development of economic technology for exploitation of low grade nickel ores have again brought oxide-silicate nickel ore to the forefront. It has been generally established that silicate and oxide ores of nickel are associated with and produced from weathering of ultrabasic periodititic rocks. These rocks have higher nickel content than average and undergo weathering under tropical conditions to produce secondary residual material in

which nickel may be concentrated up to 3 per cent. There is still uncertainties about the exact nature of nickel in these ores. Nickel replacing Mg in hydrated magnesium silicates have been found in mineral of garnierite series. But no individual mineral of nickel has been identified in most of the ores.

Investigation of nickel in ultrabasic areas of India started several years back. Studies have been made in Manipur, Andaman and Orissa areas. Significant extensive occurrence of nickel associated with weathered serpentine rocks and the residual cover with nickel content over 0.5 per cent were found in Andaman and Manipur. The material is silicate in type. Preliminary investigation has been carried out at the National Metallurgical Laboratory on the possibilities of extraction of nickel from nickel-rich weathered products from Manipur. The Cuban method of reducing-roasting and ammonia leaching was found to show good promise. More detailed work on pilot plant scale need be carried out.

Simlipal and Sukinda areas in Orissa with ultrabasic rock occurrence and lateritic covers were studied in greater detail and work is still continuing in these fields. Compared to Manipur and Andamans, proximity of these areas to industrial centres has encouraged further detailed investigation. Interesting observations have been made by Tak in Simlipal and Banerjee in Sukinda. In both the areas enrichment of nickel in the residual products of weathering of ultrabasic rocks have been observed. Geochemical sampling and analyses indicate high nickel content in soil, laterite and weathered rock near surface. Anomalies over 4000 p.p.m. were found. Isolated samples showed nickel content over 0.5 per cent. In Simlipal area the anomalies have been observed in laterite associated with ultrabasic rocks. In the Sukinda area more enrichment of Ni was observed in the limonitized ultrabasic walls in the vicinity of chromite bodies associated with early olivines rather than in the general laterite cover. In both the areas in Orissa nickel enrichment was maximum near the contact of weathered material with the unweathered rock. This contact zone seems to be the geological control. But non-uniformity and local variation of the weathering reaction make it difficult to apply this geological control for positive location of the enriched zone. Results of detailed field work in this direction are still awaited.

It was considered that some investigation on the state of nickel in these enriched residual products of weathering will throw light on the course of weathering reaction and thereby may be of help in locating enriched zones. Moreover, any process of extracting nickel from the enriched material will depend on the nature and state in which nickel is present. With this idea in view studies with some laterite samples from Simlipal and Sukinda were carried out in the Central Chemical Laboratory of GSI. The investigation is still continuing ; some of the results are briefly presented here. The samples studied were typical of the area, though some of the samples were not high nickel content.

In one series of experiments distribution of nickel in various size fractions were investigated. Sieve analysis was carried out and nickel content of different fractions were determined. Results are given in Tables 1 and 2.

Table 1—Distribution of nickel in various size fractions

Sample No.	Size fraction (Sieve No.)	Ni, %	Sample No.	Size fraction (Sieve No.)	Ni, %
I	20	0.43	IV	20	0.33
	50	0.44		50	0.35
	80	0.44		80	0.36
	150	0.41		150	0.35
	−150	0.46		−150	0.37
II	20	0.33	V	20	0.47
	50	0.34		50	0.50
	80	0.37		80	0.53
	150	0.39		150	0.51
	−150	0.41		−150	0.50
III	20	0.35	VI	20	0.49
	50	0.35		50	0.51
	80	0.36		80	0.51
	150	0.36		150	0.49
	−150	0.32		−150	0.48

Locality: Simlipal, Orissa
Sender: Shri M.W. Tak

Table 2—Sieve analysis

Sample No.	Size fraction (Sieve No.)	Ni, %	Sample No.	Size fraction (Sieve No.	Ni, %
N1	20	1.48	N/7A	20	1.13
	50	1.34		50	1.10
	80	1.30		80	1.10
	150	1.27		150	1.11
	−150	1.45		−150	1.11
N/4A	20	0.28	N/7C	20	1.10
	50	0.28		50	1.03
	80	0.21		80	6·07
	150	0.21		150	0.97
	−150	0.36		−150	1.10
N/6A	20	1.39	N/8	20	1.18
	50	1.31		50	1.11
	80	1.32		80	1.10
	150	1.27		150	1·20
	−150	1.26		−150	1.10
N/6B	20	1.25	N/15	20	1.26
	50	1.20		50	1.22
	80	1.34		80	1.15
	150	1.25		150	1.16
	−150	1.10		−150	1.14

Locality: Sukinda Chromite Belt, Orissa
Sender: Shri P.K. Banerjee

Table 3—Detailed analysis of laterites with different nickel content

Sample No.	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	TiO_2 %	Cr_2O_3 %	MnO %	NiO %	P_2O_5 %	Na_2O %	K_2O %	L.O.I. %
K1/BC. 134	24·49	21.53	34·01	1·42	Trace	0·89	0·27	0·46	0.28	Trace	Trace	0·26	16·01
KL1/BC. 36	19·40	18·55	41·80	1·72	do	0·95	0·78	0·48	0·58	0·23	do	0·30	14·86
KL1/BC. 59	27·34	13·85	33.60	6·08	do	0·81	1·23	0·52	0·52	0·15	do	0·31	15·75
KL2/BC. 8	26·66	17·11	36·40	1·61	do	0·93	1·30	0·42	0·61	Trace	do	0·75	13·92
KL2/BC. 23	23.42	14·21	42·20	1·70	do	0·79	1·16	0·50	0·50	do	do	0·50	14·93

Locality : Simlipal, Orissa
Sender : M.W. Tak

Tables 1 and 2 show that nickel does not vary much with size between 20-mesh and below 150-mesh. This indicates that nickel is associated with secondary reformed material which has wide ranges of size fractions. There is not much association of nickel with unweathered rock particles having size over 20-mesh.

The second series of experiment was carried out for gravity concentration with a laboratory Jig. Separation of fractions below and above sp. gr. 2.6 did not show any significant difference in nickel content. In another series of experiments samples were subjected to magnetic separation into magnetic and non-magnetic fractions. It was found that magnetic fraction constitutes more than 90 per cent and this fraction had higher nickel content than the non-magnetic fraction.

Detailed analysis of laterites from Simlipal area with different nickel content were carried out. The results are given in Table 3.

The results show that in these samples laterization has not proceeded to completion ; considerable amount of SiO_2 has been retained in the samples. The results also show that the MgO content is rather low and that there is little correlation between MgO content and NiO content. This indicates that nickel is not occurring by replacing Mg in the host minerals of hydrated magnesium silicate.

X-ray and DTA studies of the mineral components of some of the samples show that the major minerals are hematite, goethite and gibbsite.

Further investigations are necessary for defining the exact state in which nickel is occurring in the residual weathered material. But the evidences so far collected suggest that nickel is present as oxide or hydrated oxide along with iron oxide minerals. The iron exides which are enriched with nickel are magnetic in nature. Banerjee also reached similar tentative conclusions from his studies from other angles.

Summary and recommendations

(1) Secondary residual materials produced by weathering of ultrabasic rocks in Simlipal and Sukinda areas in Orissa show considerable enrichment of nickel.

(2) Suitable geological control for the enriched zone such as the contact with the weathered and unweathered rock need be studied in further detail.

(3) Occurrence of nickel as oxides or hydrated oxides associated with iron oxide minerals should be taken into consideration for any project on geochemical survey and sampling.

(4) Magnetic properties of this iron oxide, which contain most of the nickel enrichment need detailed study for possible application of geophysical method in locating enriched zone.

(5) Detailed study of mechanism of the laterization reaction leading to the enrichment of nickel in the iron oxides will be of real help in prospecting for new deposits.

(6) Suitable commercial process for extraction of nickel from this oxide type of ore need be investigated.

Problems of Self-sufficiency in Mineral Industry

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The Council of Scientific & Industrial Research has planned to discuss the vital problems of utilizing the internal resources of the nation, the scientific and technical know-how for developing the industrial potentialities in India at an opportune moment. In a recent issue of the Planning Commission magazine, *Yojana*, one of the articles commenting on self-reliance has concluded: "Self-reliance in both agriculture and industry within a reasonable period of time is practicable objective for India's economic policies".

The utilization of the available essential raw materials absolutely necessary, at the time of emergency, has been amply borne out during recent months, when several of the exporting countries, on whom we had been depending so far, stopped giving supplies of various commodities to India. Also equally important is the realization of the fact that this objective can only be achieved by our own efforts, by utilizing our own raw materials, talent and indigenous industry. Scientists and technicians should immediately develop proper substitutes with indigenous raw materials, as quickly as possible, so that dependence on foreign supplies for such essential materials is reduced and eliminated wherever possible.

This article is intended to highlight the problems related primarily to the pelletization of iron ore fines and the base metal substitutes.

Metals and minerals provide the foundation on which rests the industrial, technological and defence potential of a modern nation. It is, thus, of vital importance to exploit the available mineral resources and to develop the necessary technical know-how to extract usable metals and produce the important alloys for the prosperity and the survival of the nation.

India has sizeable deposits of iron, aluminium, manganese and chromium minerals, but she has not been gifted by nature with several other vital metals like nickel, cobalt, molybdenum, tungsten, niobium, etc. We, of course, have some limited deposits of copper, lead, zinc and vanadium. The short supply of these vital metals is a very serious set-back to the alloy industry of India, either for the prosperity of the nation or for meeting its defence requirements.

Pelletization of iron ore fines

There are a large number of problems faced by our mineral and metal industries. I have selected some of them for focussing our attention in the discussion today. We know that India has vast resources of iron ores; and as also, the iron and steel technology has somewhat changed during the past century. The impact of the modern requirements envisages a review of the problems associated with the exploitation and utilization of the iron ore deposits. It is planned to produce nearly 70 million tonnes of iron ores at the end of the Fourth Five-Year Plan, as against the projected output of nearly 32 million tonnes during the current year (1965–66). But most of the Indian iron ore deposits contain nearly 30 to 50 per cent dust or powdery ores, i.e. material below 1.25 cm. size. In addition to this, another 10 to 15 per cent fines are produced through blasting, etc. during the process of mining. In other words, for every tonne of run-of-mine ore nearly one-third, in certain cases even more than that, will be obtained as fines which cannot be utilized as such in our steel plants. Thus, they are at present disposed off as waste dumps during mining. On the assumption of minimum of 35 per cent of such wastage, it can be calculated that in 1970–71 (at the end of the Fourth Five-Year Plan), in order to produce 70 million tonnes of iron ores, directly usable in India iron and steel plants, or for exporting outside, we will actually have to mine 94.5 million tonnes, an excess of 24.5 million tonnes of the production required. Obviously, this will involve colossal wastage. Furthermore, it would also increase the cost of production, and would thereby affect the overall cost of production of steel and also create a problem for dumping and storage at the mines.

The main problem of utilizing these iron ore fines, i.e. ores below 1.25 cm. size, is their unsuitability for being fed to the furnaces. Such fines, if they are allowed to be fed to the furnaces, will succumb the steel industry or even if the low grade ores are used they would produce the same result. It, therefore, becomes imperative that all steps should be taken for agglomeration studies by pelletizing, briquetting and sintering to make the ores suitable for direct metallurgy. It is gratifying to record that sintering plants have already been installed at Jamshedpur, Bhilai, Rourkela and Durgapur. This, of course, has solved some of the domestic problems, but the technique of pelletization has to be developed more extensively, not only to meet the indigenous requirements but more extensive pelletization should be carried out for the export purposes, on the lines of the sintering plant set up in Goa. In the western countries, the blast furnaces are switching over to the pellets and as a consequence to this progressive change over, the demand for the Indian iron ore is likely to dwindle in such countries. It, thus, becomes obligatory to the Indian iron ore trade to prepare itself from now on to face this eventuality.

Beneficiation of low grade raw materials for steel industry

The restricted supplies of metallurgical grade coke and flux-grade limestone have become a source of anxiety to our steel industry. More extensive efforts have to be made on accelerating the beneficiation of coal and limestone for upgrading the low grade deposits and make them suitable for the metallurgical industry. Though there are some coa washeries in India, which are used for upgrading the quality of coal, very little so far has been done on commerical basis for the beneficiation of the unsuitable limestone deposits.

Aluminium industry

India has very extensive resources of bau: for aluminium metal. Extraction of alumii supplies of very cheap electric power, which ı the expansion of the industry to ease the p copper, zinc, etc. The government envisag 400,000 tonnes of aluminium per annum in the in this regard should be vigorously pursued.

Copper industry

An assessment of the copper production in the end of the Fourth Five-Year Plan there w tonnes of copper metal, but our anticipated pr Indian Copper Corporation Ltd, the only copı is planning to replace its old smelter of 7,200 to a new smelter of 16,500 tonnes capacity. of self-sufficiency steps should be taken to ex least 10,000–15,000 tonnes of copper from Ral tonnes from the Khetri deposits.

Magnesium industry

It may again be mentioned that no industr in the extraction of magnesium metal from tł site. There are large reserves of magnesite depc and in Salem district, Madras. These depos: for the extraction of the light metal, mag source for extraction of magnesium metal is ı another source of inexhaustible reserves of m and the bitterns. India has long coastlines an obtained from the seawater by desalinatio developed, the desalination would be useful d dissolved in seawater would be extracted anc water would be made available for domestic economical and effective process for desalinatic the salt is extracted under the influence of a purified water is made to flow in storage tank. be obtained from the salt concentrates by ad(technique.

Recovery of vital metals

Considerable quantities of metal scraps, drc late in various manufacturing industry d galvanizing and electroplating. Proper arrang from these are often lacking, resulting in the r scraps. This results in the loss of valuable vita imported involving high foreign exchange.

Steps should also be taken to stop or m byproducts during metallurgical processes of s: as at present nearly all the sulphur, selenium, ı not at all recovered during the extraction of c(

In Rakha area of Bihar, the sulphide mineral sulphides and bear metals like nickel,

silver etc. even though in small quantities. Attempts should be made to exploit these ores more fully and suitable smelters should be set up with advance metallurgical techniques to extract the various metals including the nickel in them.

Similarly, considerable germanium is also lost from some of the Indian coals containing this valuable semi-conductor metal. The coal-ashes from Singareni (Andhra Pradesh) and Garo Hills Assam) coalfields and also the lignite deposits of Jammu and Kashmir might be considered as suitable sources for germanium. The possibility of recovering this metal may be examined critically from these sources.

Substitute alloys

It is of paramount importance to develop indigenous substitute alloys to eliminate or at least reduce the use of alloying elements, like nickel, cobalt, molybdenum, tungsten, lead, zinc, cadmium, copper, antimony, tin etc., which are either in short supply or not available in the country. The ultimate aim of such substitute materials, made through judicious combinations of alloying elements indigenously available, is to develop alloys, conforming to the requirement of physical properties and specific service performance, characteristics of standard ferrous and non-ferrous alloys in industry and defence.

The essential alloying metals in ferrous metallurgy, specially low alloy steel, are manganese, chromium, nickel, vanadium and molybdenum. We have some resources of low grade nickel and some vanadiferous magnetites, but practically no occurrence of molybdenum so far proved for commercial exploitation. The position of molybdenum, which is required for grain refinement, high tensile strength and avoiding temper embrittlement, is specially critical, since the metal is in short supply all over the world. To a certain extent this metal, molybdenum, can be substituted by nickel. Even though there is no nickel metallurgy in India, a good amount may be recovered from old scraps and nickel bearing coins and also as a byproduct from the copper industry. Indian coins with nickel and copper may be replaced by aluminium-magnesium light alloys, as in the recent 3 and 2 paise coins. The nickel bearing laterites of Orissa may also be considered as additional potential source for this metal.

In the copper belt of Singhbhum district, Bihar, in the Uranium mines at Jaduguda near Rakha, it has been reported that the concentration of nickel is quite high in ore bodies at deeper levels. At present the entire material is mined and stored on the surface awaiting the extraction of uranium from these by the Atomic Energy Department. It might prove useful to mine these deposits for the extraction of nickel, and uranium be recovered as byproduct. The Atomic Energy Department is possibly alert to this problem and will incorporate suitable measures in their flow sheet for recovery of this metal. I venture to suggest that while attempting for the extraction of such metals from these deposits, the economic considerations need not be given the prime importance, especially in view of the short supply of these strategic minerals and in consideration of their urgent requirements for defence production.

There is a great demand for stainless steel for public consumption as utensils, as well as by laboratories and industries in handling corrosive chemicals. Nickel normally used in stainless steel may be saved by using the manganese-chromium-nitrogen steels. The National Metallurgical

Laboratory has developed a special kind of nickel-free asustenitic stainless steel, which is composed of chromium, manganese, carbon, nitrogen, molybdenum, vanadium, titanium and silicon in varying proportions. No commercial production of this substitute has yet been commmenced. I hope the NML is looking into the problem.

India is also poor in tin, zinc and cadmium, all of which are used for protective coating of iron and steel. Process of aluminizing, wherever possible, may be developed as a substitute. Since our base metal resources are quite poor, copper, lead or zinc, base alloys should be substituted by aluminium and light alloys, as far as practicable. A good portion of zinc, consumed in zinc base die casting, may be replaced by aluminium-silicon.

Lastly, copper, being so deficient in the country, the use of brass may be restricted only to essential industries. It may also be added that brass used in the manufacture of utensils, metal handles, hinges, gas and water taps are costly luxuries for a country, like India, which is so deficient in copper and zinc. Steel with protective coatings should be utilized for such purposes. Polythene pipes and taps for water supply are gaining prominence and should be used more extensively in place of galvanized pipes and brass taps.

Industrial diamond

Another important mineral needing attention is the industrial diamond which is used in several industries, like the manufacture of drilling bits, the abrasives, etc. The present requirement of diamond bits in India is estimated to be of the order of 25,000 bits a year against an installed capacity of 30,000 bits per year on single shift basis. This requires nearly 300,000 carats of diamond of industrial quality. The indigenous production of diamond stands at about 3,000 carats per annum, of which 60 per cent is of gem variety. Even if the entire quantity of 1,200 carats of indigenous industrial diamond is made available to the bit manufacturers, only about 30 bits of NX type can be manufactured annually, which is insignificant compared to our annual requirement. All the manufacturers in India procure their requirements either from their collaborators in UK and France or through the Diamond Syndicate in London, involving a large amount of foreign exchange.

The drilling bit manufacturing industry in the country is facing a great crisis and as a consequence the progress of mineral exploration is greatly hampered. In order to overcome the shortage of industrial diamond it may be worthwhile to consider suitable ways and means to either minimize the use of diamond bits or to substitute the natural diamond with artificial material, even if its efficiency and performance be slightly inferior to the natural diamond. In this connection it has to be emphasized that the used bits should be sent for resetting at the proper time to obtain the maximum amount of salvage, instead of the present normal practice of using the diamond bits to the last carat, resulting in appreciable quantity of diamond being discarded. Chilled shots or tungsten-carbide bits, should be used wherever possible to economize on diamond bits. It is also worthwhile to investigate the possibility of manufacturing artificial diamond or any other suitable material which could be substituted in the place of natural diamond.

While concluding it may be mentioned that self-sufficiency, in defence production and in industrial development, is a challenge to the scientists and technicians of the country, and will have to be met by all of us squarely.

Groundwater Resources of Mysore and their Utilization

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Mysore is one of the Southern States in Peninsular India and covers an area of approximately 73,532 square miles with a population of 19 million. Geologically, it forms part of the Precambrian shield and is almost wholly composed of gneiss and metamorphic schistose rocks which are not particularly suited for groundwater storage.

Water is a precious commodity over a great portion of the State. Surface water has been used to the maximum by building innumerable tanks, but the enormous losses through evaporation sets a limit to surface water storage and development. The population in the semi-arid regions. therefore, have to look to groundwater for their domestic and agricultural needs. The systematic study of groundwater conditions with a view to evolving a good management of groundwater resources is a matter of urgent necessity. The development of vast areas of the State, for industrial and agricultural purposes depends primarily on the systematic exploitation of groundwater.

Geological background

Although the broad geological information is available over a greater part of the State, basic data on the groundwater characteristics of the different formations are absent.

Mysore State excepting for the narrow coastal strip is largely a plateau at an elevation of 2,000 to 3,000 ft above sea level. It is composed predominantly of crystalline rocks which are impervious to water. Conditions favouring accumulation of abundant supplies of groundwater as in unconsolidated sedimentary formations, is, therefore, largely absent in Mysore.

Over a greater part of the State, however, there is generally a mantle of loose soil and decomposed rock varying in thickness from a thin film to as much as 100 ft. The average thickness of this capping may be taken at 50 ft. This decomposed zone consists of sufficiently porous material capable of holding 1/4 to 3 gal. per cu. ft and acts as a vast reservoir of groundwater.

Groundwater potential

Most of the dug wells in the State are confined to the zone of decomposition and intercept water when they reach the saturation zone. The

yield of water in these dug wells is not large and averages 250 to 300 gal. per hour. In order to obtain increased supply, large diameter wells are dug at favourable locations. These yield from 15 to 20,000 gal. per day and are mainly used for irrigational purposes. Exceptional yields of three to four lakh gallons per day are also recorded in the case of a few wells.

Based on the fluctuation of water table in the wet and dry seasons it is estimated that a zone of 10 ft in thickness gets alternately charged with groundwater and gets discharged through utilization or lateral flow into lower reaches. The quantity of water that can be held in this zone with a porosity factor of 20 per cent is 1 gal. per cu. ft. Each acre of ground therefore will hold 435,600 gal. of water or 278,784,000 gal. per square mile. This represents the water bearing capacity of this zone. About half this quantity or 140 million gallons can be expected to be available for utilization. Under favourable conditions we can, therefore, plan for utilization of 140 million gallons of water per square mile. If we take an average of 280 pumping days in a year, the estimated yield would be ½ million gallon per day in an area of one square mile.

Detailed pumping records in some of the deep seated mines as at Kolar and Hutti where groundwater is being pumped continuously over a period of years shows that the yield amounts to as much as 1 million gallons per square mile.

The groundwater potential may, therefore, be taken to vary between ½ and 1 million gallons per day per square mile depending upon rainfall, degree and depth of weathered zone and the topographic location of the area.

This quantity thus represents the annual underground supply which is available for utilization. The quantity that is actually utilized forms a negligible portion of this available annual supply.

Groundwater utilization

Groundwater at present is mostly tapped from shallow dug wells. Natural springs are rare. Water occurs in watertable and not artesian conditions. Drilled wells are not common and are located either in towns for Municipal Water Supply or within industrial establishments. Bore wells are not found in rural areas and have not yet been used for irrigational purposes. Most of the drilling is carried out by Government through the Public Works Department. Recently one or two firms have started drilling on contract.

A successful bore well yields on an average 800 to 1500 gal. per hr. This yield can be maintained for ten to twelve hours a day, allowing rest of the time for recuperation. This means that each well can yield continuously at the rate of 10 to 15,000 gal. per day. With this rate of supply it should be possible to irrigate two to three acres of land. Since bore wells can be spaced at intervals of 500 to 1000 ft without causing undue interference a good portion of the land in favourably located valleys can be brought under intensive cultivation and development.

Indiscriminate digging of shallow dug wells all over the country without a proper plan results only in waste of funds without in any way making effective use of groundwater. Such attempts should be confined to particular valleys and they should be integrated so as to supply water through pipes and channels to larger areas. Wherever land owners have settled on

their farms and have started planned management of their farms through groundwater development by means of dug wells and drilled wells, a great improvement is noticed. It is necessary to carry out studies in pilot farms extending over an area of 50 to 100 acres, preferably in silted up and disused tank areas and evolve a farming pattern through groundwater utilization. The economic feasibility of such programme should be clearly demonstrated. This can be followed up at a later stage by carrying out statewide surveys for utilization of shallow groundwater for agriculture.

Basic studies

In order to be able to give dependable advice on water supply schemes based on groundwater resources, a great deal of basic work is necessary. A few such items are listed below :

(i) There is at present no agency responsible for collection of information relating to wells. There should be a permanent agency collecting basic data, including the rock types encountered in the well and their character, depth of well, depth to water and rate of lowering of level at a given rate of pumping. An inventory of wells should be maintained and brought up-to-date. This data will enable to draw a watertable contour map.

(ii) The study of fluctuation of watertable in certain observation wells in each district must be carried out in order to make an assessment of the annual groundwater rechange.

(iii) Porosity, permiability and specific yield characteristic of different types of rocks and their altered products have to be determined.

(iv) Studies relating to estimation of moisture content of soil samples at different depths and during different seasons of the year to evaluate the loss of groundwater through evapotranspiration.

(v) Collection of information relating to run-off-characteristics of not only major rivers but minor streams. A large number of stream gauging stations have to be established and records of run off maintained. This information extended over a period of years along with figures of rainfall will enable estimate of groundwater enrichment each year.

(vi) Systematic geophysical investigations, especially those based on earth resistivity to be carried out in order to find the depth of alteration and depth to bed rock. This information will help in better siting of bore holes and eliminating chances of failure.

(vii) Since groundwater is primarily dependent on rainfall, ways of preventing absorption of rain water by adopting appropriate methods of cultivation, aforestation of the watershed zone, prevention of soil erosion through contour bunding, etc., has to be studied and adopted.

A good part of Mysore State falls in the arid and semi-arid belt. The prosperity of these tracts depends to a large extent on the availability of water. It is estimated that the yield from an irrigated land is nearly four times that of the yield from an unirrigated dry land. It is, therefore, essential that as large a portion of land should be brought under irrigation as possible. Major irrigation works take several years to complete and involve huge investment of capital. Large tracts of excellent land get submerged. Well irrigation through groundwater development yields quick results and the investment is less.

What is urgently required is a feasibilty study of utilization of groundwater for agriculture, by establishment of pilot farms in selected parts of the State and working out the economics of a programme of development of groundwater through drilling bore wells and large diameter dug wells.

It should be recognized that underground water is more precious even than precious metals and industrial minerals and requires to be surveyed, mapped and explored systematically more intensively than other minerals.

सत्यमेव जयते

Exporting Upgraded Minerals

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A process has been developed which results in concentrates of attractive grades, not obtainable by usual ore-dressing methods. For example, ferruginous bauxites, brownish-red in colour can be upgraded into a brilliant white grade with only a trace of iron ; similarly, a low grade chromite can be upgraded to a high chromic oxide/iron oxide ratio. The results obtainable are typified by the following analyses :

	Raw bauxite	*Upgraded bauxite*
Colour	Brownish red	Brilliant white
Iron oxides	4.6%	Trace
Titania	2.7%	2.6%
Silica	1.1%	1.7%
Alumina	55.8%	89.2%

The process results in products of much enhanced value than obtainable by usual dressing methods alone. The processed bauxite above can successfully compete with Bayer's process alumina for iron free applications by chemical and ceramic industries. The sulphation is as easy as that of gibsite.

Amongst the reasons for the present slump in the mineral export trade is the introduction of superior materials in the world market by fast developing countries of Africa, Australia and South America. The unique position which India enjoyed as a supplier in the world market was thus shaken by the development of well organized, adequately financed, conveniently near, and materially superior sources of minerals in the consumer market.

Obviously, then the most effective thing which can be done to regain part of the lost trade, is to offer to the world market even superior grades of minerals which can be obtained by special processing the crudes under conditions not obtainable abroad.

Upgrading of minerals by conventional beneficiations methods are restricted to mechanical devices making use of differences of physical properties of the mineral constituents. These processes include such well-known methods as gravity separation, magnetic separation, froth-flotation etc. Although cheap any where, these processes have a limited scope in that they are able to separate what is physically separable. They have

very limited scope in cases where the impurities occur as well-dissiminated material as in case of iron oxide in bauxites, or they may occur as chemical molecular combinations as in case of ilmenite or chromite.

It is too tragic that we have lost our trade in ilmenite which has been for fifty years considered the world's best. The shift of the pigment producers to the chloride process of titania manufacture has shifted the demand from ilmenite to rutile. The electric slag manufacture resulting into 75 – 85 per cent titania is also responsibile for the shift from high grade ilmenite to medium grade cheaper sources.

Similarly, our position with regards to bauxite export also has been none too happy. The west-coast bauxites are conveniently located well within a mile from the shores. They also happen to be highly gibsitic in nature and very favourable for easy digestion by the caustic as in Bayer's process. In fact this author has by extensive testing found that even atmospheric digestion with comparatively weak solutions can yield as much as 95 per cent extraction of alumina in half an hour[1], yet, they have failed to fetch any export interest. Our chromite exports have had to contend with mediocre grades, and have never enjoyed competitive position in the world market.

Chemical processing needed

Obviously, then what cannot be obtained by physical separatory processes has to be accomplished by a chemical process. Such chemical reactions are known to preferential attack one of the constituents leaving behind a richer fraction. Thus selective reduction of iron oxides have been suggested and commercially developed in case of ilmenites and chromites. The processes range over a wide area, and include solid state reduction, fusion reduction, and semi-fused state reduction by a number of reducing agents like coal, coke, carbon monoxide, hydrogen, natural gas etc. The processes suggested used a wide variety of equipment ranging from stack furnaces, electric furnaces, rotary kiln, tray type kilns, fluidized bed reactors, etc.

One of the main difficulties of this high temperature reduction process was the separation of iron from the slag. The slag contained the valuable ingredient of the crude ore. It was considerably altered in physical and chemical characteristics and the further treatment had to be considerably altered.

Chlorination as upgrading process

Chlorination has been increasingly resorted to as a commercially successful process on minerals. Today such minerals as rutile, zircon, magnesite etc. are being regularly processed by chlorination. Development of materials of construction has taken much of the hazards of chlorine. The author had an occasion to visit a plant in USA producing titania pigment by chlorination of rutile, and oxidation of titanium tetrachloride. There was not a whiff anywhere in the plant of either chlorine or the chlorides. The materials used had been in service for a long time and was highly automated.

Chlorination is specially attractive under Indian conditions, because of the abundance of surplus chlorine in many localities. The present estimate of chlorine going to waste is around 30 per cent. Although the new coming organic industries are estimated to consume additional quantities of chlorine there is also plan to further expand the caustic soda capacity to

meet the fast increasing needs. Obviously, the additional coproduction of chlorine at the rate of 0.85 ton per ton of caustic and an equivalent amount of hydrogen is likely to keep the figure of chlorine utilization at 70 per cent. By the end of the Fourth Five-Year Plan over 100,000 tons of chlorine will have to be disposed off, annually.

In Bombay area alone, two of the producers having a combined capacity of about 80 tons per day of chlorine have to dispose off about 50 tons of the same per day. The prescribed method of disposal calls for burning the surplus gases ; neutralizing the acid gases with lime slurry and draining the neutral chloride into creek. It is estimated this method of disposal should cost about Rs 2000 per day for disposal of the surplus gases every day.

It is thus obvious that this national waste is available for utilization, and if it could be utilized for upgrading medium grade minerals for export at profit, it should be done with top-most priority. Caustic soda chlorine plants with their surplus waste gases thus provide an excellent opportunity for mineral processing which is generally not readily available in foreign countries. We are thus in a unique position to make the best of this situation for regaining the lost export trade.

Chlorination of minerals : Earlier processes

Early efforts at chlorination of minerals have varied under a wide range of conditions as described below :

(i) Processes using chlorine alone,

(ii) Processes using chlorine with solid reductants like coke, charcoal, sulphur, pyrites, etc.,

(iii) Processes using chlorine with gasous reductant like carbon-monoxide,

(iv) Processes using chlorine as a compound like phosgene, sulphur chlorides, anhydrous hydrocoloric acid gas, etc.,

(v) Processes using hydrochloric acid solutions under pressure.

Use of chlorine alone has been reported[3] as recently as 1963. It suffers from a major disadvantage that it is a highly endothermic reaction in case of most of the oxide and silicate minerals, although an exothermic one in case of sulphides. In case of the most of exportable Indian minerals, the reaction is highly endothermic needing large amounts of heat supplies from outside source to maintain the reaction velocity high enough for commercial operation. Thus Kitteridge chlorinated ilmenite by chlorine and found a temperature of 1100°C. necessary. The investigation lost its practicability when confronted with the problem of heat transfer to the charge from outside through the refractory lined steel shell. From engineering point of view this is held as an impractical proposition[3].

Use of chlorine in presence of solid reductant like carbon in various forms, has been a subject of large number of patents[4-9]. Although the heat requirements are moderated by the presence of the reductant, the problem of contamination of the valuable residue in case of the selective chlorination, by the high ash Indian coke, or the problem of product-chlorides by the chlorination of the ash constituents is a serious disadventage. It is also reported[10] that selective chlorination becomes difficult,

Use of carbon monoxide[11] is only mildly exothermic and effective in case of the more amenable minerals. In small reactors with greater proportion of heat losses, the reaction would not be self-sustaining in the case of more refractory minerals. It is thus likely to raise the same problems of heat transfer as the use of chlorine gas alone.

Use of chlorine compounds has also been advocated and patented. The highly poisonous gas phosgene was used by the Germans for chlorinating bauxite for the manufacture of aluminium trichloride anhydrous[12]. A US Patent[13] advocates the use of carbon tetrachloride. Others have used even costlier sulphur-chlorine compounds which are also unavailable in tonnage quantities. Further, every part of chlorine admitted into the reactor, is accompanied by a fixed amount of the compounded element, whether it is needed or not. They give rise to a number of side reactions.

Use of anhydrous hydrogen chloride gas is covered by an Indian Patent[14]. This process calls for passing the HCl gas over a heated charge, e.g. ilmenite heated to 800 – 1000°C. when selective chlorination of iron oxides takes place, leaving behind a titanium rich residue. This process is also handicapped by the need to supply large amounts of heat to the charge, since the reactions involved are unable to sustain the charge at the reaction temperature. The second disadvantage is that introduction of HCl gas poses a measure of inflexibility of proportion of hydrogen to be admitted to the reactor.

A-BUDOCT process

A process developed by the author as the Bombay University Department of Chemical Technology overcomes the above-mentioned disadvantages—particularly the need to supply heat externally and also an introduction of a great measure of flexibility over the chemistry of the process which would enable a large number of minerals including the more refractory ones as also slags, drosses, metals, and other inorganic compounds.

The A-BUDOCT process comprises obtaining an intimate mixture of controlled rates of minerals, chlorine and hydrogen in a reactor preferably of the fluidized bed type. The resulting overall reactions are so exothermic as to maintain the charge at as high a temperature as 1300°C. and does not need any supply of external heat. Further by suitably manipulating the ratio of hydrogen gas proportion a wide range of temperatures and cholorinating conditions can be obtained, to suit a large variety of minerals.

The A-BUDOCT process can be conducted in a large variety of reaction chambers. It has been tested on local minerals on continuous basis and has been proved very successful. For example it can be carried out in vertical glass columns with conical fluidizing stem holding ports of gas entries at the bottom. The hydrogen gas is lighted first and the chlorine gas is admitted by other ports. The mineral introduced from the top by a continuous screw feeder is immediately fluidized and vigorously participates into a reaction. The gas proportions can be adjusted to give a maximum reaction rate. Introduction of other hydrocarbon gases or town gas has also been successfully tested along with steam and air.

The process has resulted in rapid conversion of ilmenite of 60 – 61 titania content to a rutile of 94 – 96 per cent titania content. Similarly, treating reddish-brown ferruginous bauxites containing 4.5 – 5.5 per cent

iron oxides and 54 – 56 per cent alumina contents, a product free from iron oxides and containing 90 per cent alumina and having a brilliant white colour has been obtained. It is at once obvious, that such a treated bauxite can successfully compete with Bayer's process alumina which is very much in short supply in the country, for all iron free applications by chemical and ceramic industries. The reactivity of this treated bauxite with sulphuric acid compares favourably with that of gibsite.

The value of the products obtainable from this process is several times more than the crude ores being treated. The products are in great demand in the country and abroad and can successfully compete with minerals from other sources in free world market. This obviously is one way to recapture the lost place in the mineral trade abroad.

The process has been tested on continuous basis on scales large enough to give preliminary costing data. It is estimated that a plant costing Rs 50 lakhs can pay for depreciation, interest, all operating costs, and earn enough margin to pay for the plant in about four years. The costing has been done allowing decent prices for all raw materials and not on distress sale. The process is available for licensing to interested parties.

Another important feature of the process is the *in situ* neutralization and production of near-neutral salts mostly iron salts, which can be disposed off at nominal rates for water treatment. The violent and corrosive nature of the flame reaction is so tamed that even glass columns have been in continuous use in our laboratories without a single break or mishap. It is estimated that except for a few of the control components, the entire commercial plant can be locally fabricated.

India has many locally available marketable minerals which could be thus upgraded and offered in very attractive grades to the world market and thus our export trade can be revived to bring in the much needed foreign exchange.

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